

The University of Chicago

A TECHNIQUE FOR DEVELOPING
COURSES IN PHYSICAL SCIENCE
ADAPTED TO THE NEEDS OF STUDENTS
AT THE JUNIOR COLLEGE LEVEL

A DISSERTATION SUBMITTED TO THE FACULTY
OF THE DIVISION OF THE SOCIAL SCIENCES
IN CANDIDACY FOR THE DEGREE OF DOCTOR
OF PHILOSOPHY

DEPARTMENT OF EDUCATION
1946

By
EDGAR ZODIAG FRIEDENBERG

CHICAGO, ILLINOIS
1946

The University of Chicago

A TECHNIQUE FOR DEVELOPING
COURSES IN PHYSICAL SCIENCE
ADAPTED TO THE NEEDS OF STUDENTS
AT THE JUNIOR COLLEGE LEVEL

A DISSERTATION SUBMITTED TO THE FACULTY
OF THE DIVISION OF THE SOCIAL SCIENCES
IN CANDIDACY FOR THE DEGREE OF DOCTOR
OF PHILOSOPHY

DEPARTMENT OF EDUCATION
1946

By
EDGAR ZODIAG FRIEDENBERG

CHICAGO, ILLINOIS
1946



ACKNOWLEDGMENT

The writer is greatly indebted to W. L. Beauchamp, R. J. Havighurst, H. A. Thelen, and R. W. Tyler for valuable suggestions and kindly and considerate guidance in the writing of this document. He is also indebted to Alvin C. Eurich, of Stanford University, for much assistance in the conduct of the investigation on which the dissertation is based, to Jordan G. Lee Jr. of Louisiana State University, for guidance in the development of instructional material and for conduct of the control course, and to Otto M. Smith, Head, Chemistry Department, at Oklahoma A & M College.

TABLE OF CONTENTS

	Page
ACKNOWLEDGMENT	11
LIST OF TABLES	v
Chapter	
PART I: INTRODUCTORY CONSIDERATIONS	
I. RECENT SOCIAL CHANGE AND EDUCATION	2
II. SOME ASSUMPTIONS OF THE NEEDS APPROACH	13
Student Welfare Is the Focus of Educational Effort	
Learning Influences Behaviour	
The Basic Faith in Insight and Rational Use of Comprehended Fact in Determining Choices of Behaviour Remains the Cornerstone of Educational Planning	
The Objectives of a Course Are Determined by the Changes Which It Is Intended to Produce in Students, Rather than by the Subject Matter Peculiar to the Department in Which It Is Offered	
Learnings Are Chiefly Useful in Situations Similar to that in Which the Learning Occurred	
PART II: AN EXAMPLE OF THE DEVELOPMENT OF A SCIENCE COURSE ADAPTED TO THE NEEDS OF STUDENTS	
III. FACTORS ANTECEDENT TO THE PROBLEM.	19
The Situation in Which the Course Was Developed	
Characteristics of the Students	
The Student in His Culture	
Responsibilities and Limitations Imposed on the Course by Oklahoma A & M College as a Situation	
IV. SELECTION, DEFINITION, AND ORGANIZATION OF STUDENT NEEDS.	37
Classification of the Needs of Students	
Selection of Problems	
Adaptation to the Experimental Situation	
V. DESCRIPTION OF THE METHOD RESULTING FROM A PRELIMINARY TRYOUT.	46
Role of the Exploratory Group	
Formulation of the Method	
VI. DESCRIPTION OF THE LEARNING EXPERIENCES.	63
Materials of Instruction	
Log of Learning Activities and Content	

Chapter	Page
VII. METHOD OF EVALUATION OF OUTCOMES.	87
Consideration of Possible Means of Evaluation	
The Design of Evaluation Instruments for the	
Experimental Course	
PART III: APPRAISAL OF SUCCESS IN MEETING	
THE MAJOR NEEDS	
VIII. APPRAISAL OF SUCCESS IN MEETING NEEDS IN AREA	
THREE	100
Brief Characterization of Area Three	
Relation of Items to Specific Needs in Area Three	
Evaluational Data	
Interpretations	
IX. APPRAISAL OF SUCCESS IN MEETING NEEDS IN AREA FOUR.	113
Brief Characterization of Area Four	
Relation of Items to Specific Needs in Area Four	
Evaluational Data	
Interpretations	
X. APPRAISAL OF SUCCESS IN MEETING NEEDS IN AREA FIVE.	121
Brief Characterization of Area Five	
Relation of Items to Specific Needs in Area Five	
Evaluational Data	
Interpretations	
XI. APPRAISAL OF SUCCESS IN MEETING NEEDS IN AREAS	
SIX AND SEVEN	134
Brief Characterization of Areas Six and Seven	
Relation of Items to Areas, and Evaluational Data	
Interpretations	
XII. APPRAISAL OF SUCCESS IN MEETING NEEDS IN AREAS	
EIGHT AND NINE.	138
Brief Characterization of Areas Eight and Nine	
Evaluation and Conclusions	
PART IV: EVALUATION OF THE APPROPRIATENESS OF	
THE NEEDS APPROACH TO CLASSROOM	
INSTRUCTION	
XIII. RANGE AND APPLICABILITY OF THE METHOD	158
XIV. THE VALIDITY OF THE ASSUMPTIONS OF THE NEEDS	
APPROACH.	168
APPENDIX A.	179
APPENDIX B.	235
APPENDIX C.	242
BIBLIOGRAPHY.	252

LIST OF TABLES

Table	Page
1. Farm Background and Vocational Goal of Students in Needs-Centered Course, According to Place of Birth	24
2. Designation of Examinations Prepared for Experimental Group.	101
3. Relation of Items on Examinations to Needs Listed for Area Three.	101
4. Results Obtained on Examination C in Measuring Objectives withing Area Three	104
5. Correct Responses Measuring Needs in Area Three Chosen by More than Half of Students Taking Examinations A and B.	105
6. Correct Responses Measuring Needs in Area Three Chosen by Less than One-Fourth of Students taking Examinations A and B.	106
7. Relation of Items on Examinations to Needs Listed for Area Four	114
8. Results Obtained on Examination C in Measuring Objectives Within Area Four	115
9. Responses on Examination C Measuring Needs in Area Four Chosen by More than Half of the Students in Experimental or Control Group	116
10. Relation of Items on Examinations to Needs Listed for Area Five	122
11. Correct Responses Measuring Needs in Area Five Chosen by More than Half of Students Taking Examination D	124
12. Correct Responses Measuring Needs in Area Five Chosen by Less than One-Fourth of the Students Taking Examination D.	124
13. Results Obtained from Examinations E and F in Measuring Objectives Within Area Five	125
14. Number of Students in Experimental and Control Groups Making Each Response on Items of Examination F Measuring Ability to Apply Chemistry to Dairy Problems.	129
15. Number of Students in Experimental and Control Groups Making Each Response on Item of Examination E Measuring Need Five	131
16. Results Obtained from Examination F in Measuring Objectives Within Areas Six and Seven	135

Table

Page

17. Number of Students in Experimental and Control Groups Making Each Response on Items of Examination F Measuring Area Six.	137
18. Classification of Attitudes of Anonymous Student Commentators	143
19. Statements Included in Comments of Anonymous Student Commentators	144
20. Comparison of Results Obtained by Experimental and Control Groups on Examinations Measuring Objectives of Conventional Chemistry Courses.	160

PART ONE

INTRODUCTORY CONSIDERATIONS

CHAPTER I

RECENT SOCIAL CHANGE AND HIGHER EDUCATION

The prevailing pattern of science courses offered in the first two years of college in most American institutions of higher learning differs but little from the program available at such institutions a half-century ago. The American university has been greatly influenced by the German research institution of the nineteenth century, and like it, has offered its science students primarily a logically organized body of subject matter intended to embody the knowledge needed by scientific specialists. The traditional college science course has expanded and altered in content as available scientific knowledge has increased, and as new theoretical formulations have replaced older ones. It has not responded similarly to changes in the nature, requirements, and goals of its clientele.

It is the purpose of this dissertation to describe, examine, and analyze a method by which courses in physical science may be adapted to the needs of students. A broad classification of needs which the writer believes to be applicable to any group of students will be formulated, and a detailed example of the reduction of such a pattern to the level of specific behaviours valid for a particular group with a common vocational interest will be given. The development of a course in inorganic chemistry designed to meet these needs will then be described and certain qualitative and quantitative evidence of the effect of this course on the behaviour of students will be presented and appraised.

The evolution of a procedure for the adaptation of college courses to the needs of students comes in response to profound social change which has already compelled the most sweeping revisions in the practice of collegiate education. During the period of the nineteen thirties, considerable attention was given to the reorganization of college curricula. While a relatively small minority of institutions undertook to change their accustomed pattern, this group was numerous, and the fact that such change tended to occur at all is significant in demonstrating that a correspond-

ing change had begun to occur in the role which a college serves. The reasons for this change are, on the whole, quite obvious.

For the first time persons of comparatively less privileged social and economic position became numerous candidates for education at the collegiate level. This does not mean that college education is available to everybody in our society. On the contrary, only about 8 per cent of adolescents of the appropriate ages complete college education, and it is generally recognized that economic factors are far more significant than academic ones in determining who those 8 per cent shall be. American secondary education, however, while still selective, is not very strongly so. About 70 per cent of adolescents of high-school age are enrolled in high school during peace times.¹ The number who graduate is a smaller proportion of the total, but it is large enough to make eligible for college entrance a complete, though not a representative cross-section of the population.

Moreover, these are typically persons who, in the pre-war economy of America, were unnecessary. Unemployment always bears most heavily on those who are just beginning to seek a place on the labor market. Rainey,² Bell,³ and others have presented evidence that a high school graduate during the period up to the outbreak of the war found it necessary to wait two to three years before finding steady employment. This, in view of the American materialist philosophy, is a truth bitter enough to mock our knowledge of the psychological and biological needs of children. An American boy is not regarded as grown up so long as he is economically dependent on his family. His self-esteem is placed in jeopardy; he must live at home among relationships which usually deny him maturity. And he cannot marry. This bar to marriage operates, of course, with equal force against the adolescent girl, whose economic problem, in view of the discrimination against women practiced in our culture, is even more severe.

These young persons, then, at the formal conclusion of

¹John Dale Russell and Charles H. Judd, The American School System, pp. 37-54. Cambridge, Massachusetts: The Riverside Press, 1940.

²Homer P. Rainey, How Fare American Youth, pp. 19-41. New York: D. Appleton-Century Co., 1938.

³Howard N. Bell, Youth Tell Their Story, pp. 101-57. Conducted for the American Youth Commission. Washington: American Council on Education, 1938.

their secondary school career, have no social role. As long as they are idle, society regards them as worthless, and rewards them proportionately. Bertrand Russell states that what we do when we are idle is usually harmless, while that for which we are paid, particularly if we are highly paid, is likely to be harmful;¹ but youth to whom no respectable social symbol is available must either live unrewarded in a little hell of inadequacy and frustration or repudiate the mores of the middle class society and seek gratification, status and significance in activities which that society regards as delinquent or criminal.

Thus, society, if it chose to seek to reduce the number of young persons making the second choice, was obliged to create a social role which would be available to them and which would grant a certain feeling of significance and self-respect. There was, of course, more than one way in which this could have been done. A sensible course of action might have been social reorganization sufficiently widespread to permit all persons physically and mentally capable of caring for themselves a meaningful role in the culture. This action could not be taken. Society could, with much less alteration of existing institutions, have undertaken, under government agency, many of the necessary functions which are not available to our people in normal times--such functions as food, clothing, housing, and medical care. Such action would, however, have placed the government in competition with existing private enterprise. The government was permitted, therefore, to undertake only activities so remote from the common economic activities of Americans as to be both non-competitive and peculiarly vulnerable to charges of inconsequence and artificiality. Only two of these, the CCC and the NYA, were designed specifically to assist young persons.

The CCC, however, was extremely limited in its appeal. Its training was physically rigorous; its organization was semi-military; its work of reforestation was valueless as vocational training to most of the young persons who enrolled in it, many of whom regarded themselves as permanently urban. But its most serious defect was its conspicuously low status value. A boy who joined the CCC could be certain of enough food and clothes to be neither undernourished nor cold. But he would have made formal

¹Bertrand Russell, Selected Papers of Bertrand Russell, pp. 287-88. New York: Modern Library (137), n.d.

declaration of indigence by the act of enrollment. In the American status system, poverty is such a serious crime that persons guilty of it can seldom maintain self-respect, and it was precisely this self-respect which most young persons most seriously needed. So the CCC was in effect available only to those in such dire straits that the physical advantages offered by it would alone repay the geographical and occupational adjustment involved. If we were a people to whom health, a feeling that our work served a socially useful purpose, and warm sympathetic relations to our peers were more important than symbols of economic status, the CCC program might have fulfilled the needs of many more American adolescents.

The only social role already available to unemployed high school students through existing social institutions was that of college student. It should be pointed out that, at best, this provided chiefly for status needs. It did not provide economic independence, adult participation in the life of the community, or marriage. But boys or girls could, by saying that they were attending college, avoid the stigma of idleness and uselessness, and convince themselves that they were providing for their own welfare.

Under the NYA, college attendance became economically possible for many persons who could not otherwise have come. It was still a highly selective process, but the very circumstances of the depression made it less so. One need not quit school to take a job, however poor one's family may be, if there are no jobs to be held. Often the meagre NYA allotment meant not only educational opportunity, but the only opportunity the young person would have to earn anything at all.

The college, however, is not designed primarily to provide asylum for students. Nor was the typical American institution designed to contribute very effectively to the growth of all the children of all the people. An examination of its antecedents shows clearly why this is so. The first American college was patterned on Cambridge University, the second on the University of Edinburgh--both institutions designed to provide the culminating experiences of leisure class and professional education strongly classical in tradition. Even during the nineteenth century it was clear that the rapidly developing American continent would require more professional and technical personnel, and

could support a larger upper middle class, than could attend the old colleges of the eastern seaboard or the numerous small, private, usually church-supported institutions modeled on them. The Morrill Act provided land grant colleges and state universities for the large clientele of the hinterland. Growing interest in science led to the formation of graduate schools specializing in research, modeled on the institutions at Leipzig and Heidelberg. Cornell and Johns Hopkins Universities were among the first of these. American higher education thus came to be almost wholly derivative and, save as it served as a pathway for the socially mobile, devoted itself wholly to the interests of the American upper classes.

There is, of course, no valid reason to suppose that the course offering of the university was well adapted to the requirements of even the limited class it served. Rather, it was irrelevant. The "Adult Study" of the University of Minnesota¹ indicates that going to college produces no reliable change in the behaviour of graduates as compared to non-graduates, within the areas apart from the students' vocational interest. His vocational curriculum changes his behaviours, but is ordinarily much more difficult than can be justified on the basis of the demands which the profession makes on him.

Attendance at an American college or university had thus apparently come to be valuable chiefly as a symbol. Regardless of the beliefs which most college administrators might hold as to the objectives of their institution, its verifiable social accomplishments were generally: (1) to demonstrate that the student possessed verbal ability and behaviours consistent with usual American middle class standards; (2) to demonstrate that the student was solvent, or so strongly motivated by the middle class values of thrift, industry, and soothing respect for authority as to constitute no threat to the established class structure; (3) to provide professional curricula of sufficient difficulty to insure that only as many candidates would succeed as the profession could comfortably absorb. This difficulty was usually achieved by intense specialization, since the American graduate school was modeled after the research institutions in Germany, though this

¹Alvin C. Eurich and C. Robert Pace, A Follow-Up Study of Minnesota Graduates from 1928 to 1936, pp. 1-41. Minneapolis: Committee on Educational Research, University of Minnesota, 1938.

specialization bore no demonstrable relation to the professional obligations of most American graduates who filled teaching positions in colleges and universities. These men taught the courses they had learned, though few of their students had professional interest in their particular subject. Since this material was useful in the training of technical specialists; since they alone were required to demonstrate that they had acquired new behaviours as a result of their educational experience; and since highly technical courses are well adapted to failing persons whose abilities are not verbal, or who must work too hard to support themselves to have much time for recondite scholarship; the selective function of the school was also well discharged.

These were the institutions available to the new throngs of high school graduates. To such as these, the educational purposes of the college were even less relevant than to the older, more privileged student groups. The social purposes were utterly unsuited. To supply the symbolic participation which these students must have in lieu of a job if they were not to be lost to the middle-class culture, an institution was needed from which they would not be rapidly eliminated. The traditional objectives of liberal education, although seldom reached even by upper-class Americans, were consistent with the picture they had of themselves as culturally superior, conspicuously leisured, financially potent persons. To most of the high school graduates of the thirties, these objectives were grotesque. Nor had the professions room for all the able persons academically prepared to enter college who might have wished to earn their living by them. Participation in the typical college of 1929 would therefore have been meaningless and difficult activity for most of the potential students of 1932.

Nevertheless, most persons who enter college are still obliged to act as if this were not the case. The reasons for this are many and complex, but may be summarized under two groups of causes: a difficulty of evaluating a role conceived chiefly as symbolic, and the basically competitive ideology of success in America. An architect whose buildings fall down on people, a surgeon whose patients bleed to death on the operating table, or a chemist whose insecticide eats holes in the wallpaper will find himself an object of scorn in his profession. People will giggle at him behind his back; he will not be offered drinks in his

club; and he will probably develop severe feelings of inferiority and frustration and be obliged to place himself in the hands of a psychiatrist. But the objectives of higher education are subject to no such obvious criteria of failure. Most college teachers and administrators do not conceive their function as one of producing specific changes in students, and society does not brand them failures if they cannot do this. They are not usually motivated to reconsider their function and proceed to adopt one requiring technics and insights unfamiliar to them. Empirically, there is every reason to believe that such behaviour is dangerous, for, if college administrators are not often discharged because their institutions serve no demonstrably useful educational purpose, they are frequently harassed for permitting realistic consideration of the society which they serve, or for opening economic opportunities to minority groups which the white, Protestant, elite ordinarily wishes to dominate.¹

Moreover, since the ideal of success in America is largely financial and competitive, there is little tendency for students to reject the highest vocational ambitions in favor of those more likely to be realized. Young persons in our culture quite frequently choose to compete for the highest goals, even though there is little room for them at the top. This tendency has been combated by restriction of enrollment in certain professional schools, often by the use of such undemocratic technics as racial quotas, and has also been partially mitigated by the bitter experiences of the depression, which has led some to relinquish the traditional American dream and to ask merely for relative security and independence at their accustomed standard. Persons having this attitude would not, in most cases, however, have considered a college education a useful tool in achieving their goal.

Thus, an ambivalent pressure came to be felt by college and university administrators. Those both alert and relatively free were motivated by recent economic developments to reexamine and reformulate the objectives of higher education, while those dominated by persons terrified by the new sense of economic instability intensified their efforts to serve as a selective institution for vocational success. Those students who chose to

¹The recent discharge of Dr. Rainey from the University of Texas and the process by which Roosevelt College of Chicago came to be formed, are cases in point.

fight their fellows most bitterly for the few remaining places found ample institutional facilities available, while newer concepts of the function of education bore fruit in institutions which sought to define their obligations to students more broadly and usually more specifically.

Certain of these newer definitions, to be sure, appeared more as evasions of responsibility than as creative attempts to meet it. Thus, the curriculum of St. Johns College, with its emphasis on the classical heritage and drill, seemed to be based on an outmoded psychology of mental faculties and general transfer of training. The University of Chicago, recognizing that the students in the first two years of its college program would not profit particularly from a program of immediate specialization, while holding an academic concept of general education, reorganized its curriculum into four large subject matter areas. The University of Florida brought forth an organization of curriculum which combined, not very logically, certain aspects of this subject matter division with courses apparently based on some consideration of student needs. "Humanities" and "General Mathematics" found a place in their General College alongside "Reading, Speaking, and Writing" and "Man and the Social World."¹

But a few colleges, recognizing the implications of social change and their responsibility for a new kind of service to students having no other appropriate agency from which to seek aid, sought to reorganize the curriculum on the basis of what has come to be called student need. The term requires clarification. It obviously derives in part from the concept of self-directive activity so characteristic of the progressive education movement. But student need, as more conservatively defined, does not always imply a felt need, originating with the student, although it should probably be restricted to needs which students will agree are valid. Student needs may originate with the student, or with the situation to which the student must, in reality, adjust; that is, the student may perceive that growth requires him to develop new technics and skills for living, or he may be placed by circumstances partially or wholly beyond his control in a situation in which new technics and skills, whose nature he cannot conceive,

¹National Society for the Study of Education, General Education in the American College, pp. 135-219. Thirty-Eighth Yearbook, Part II. Bloomington, Illinois: Public School Publishing Company, 1939.

are necessary for success or survival. This dual classification does not apply only to students. A need of the former kind led to the development of the atomic bomb; a need of the second kind for its control still exists.

For the purpose of this study, student need may be defined as a behaviour, including skills, technics, habits, or evidences of insight, which may reasonably be expected to make a student happier, healthier, and more effective in satisfactorily resolving situations which he recognizes to be problems to him. Several of the colleges which reorganized curricula in the early thirties adopted schemes of organization which sought to meet needs defined in very similar fashion. It is perhaps unfortunate, however, that, with certain exceptions, such reorganizations occurred more frequently in those institutions which serve a clientele largely protected from economic stress even in times of depression. Among the reasons for this are the relative absence of the fear which tended to drive many less privileged students along the blind alleys to traditional vocational competition; the higher cost of many of the individualized methods used in meeting student needs, which tended to restrict them to institutions capable of charging high tuition; the relative freedom of smaller, more exclusive institutions from conservative lay control; and the fact that those groups holding the power controls in America would not fear effective education of the members of the upper classes so much as effective education of those whose less privileged position caused them to need it more.

Thus three of the most significant organizations of curriculum in terms of need were found in three exclusive colleges for women.¹ Sarah Lawrence College developed highly individualized instruction based on study of the student and her problems. Bennington College did this, and added to it the formal devices of the trial major and selected and supervised work experience, designed less as vocational education than as an opportunity for the girl to discover a social role in which she might contribute. Stephens College undertook a comprehensive and direct study of the needs of its students and stated the results in the following seven-point classification:

¹Ibid.

- Needs for: 1. Training in communication by speech and writing.
 2. Appreciation of beautiful.
 3. Social adjustment.
 4. Training toward maintenance of physical health.
 5. Becoming alert, aware, and intelligent about personal and family consumer needs.
 6. Training toward maintenance of mental health.
 7. Development of a philosophy of living.¹

At the University of Minnesota, the General College was organized to meet needs within a four-point classification including personal life orientation, home life orientation, general vocational orientation, social and civic orientation.² This institution was, perhaps, the most important of all those seeking specifically to meet student needs, because it served the least selected student group. Any graduate of a high school accredited to the University of Minnesota is entitled to enter the General College, although all other divisions of the University impose certain scholastic standards in addition to high school graduation. This attempt to meet fully the needs of all young Minnesota high school graduates who wished collegiate education was the target of attack for the more reactionary members of the faculty of other schools of the University who succeeded in making many of the students of the General College ashamed to be in a "School for Morons," rather than proud to receive some of the most carefully planned and organized educational experiences available in any institution in the world.

The classification of student needs for purposes of curricular organization was, finally, rather well summarized by the Commission on Secondary School Curriculum for the Progressive Education Association which made a four-point classification: (1) Personal, (2) Personal-Social, (3) Social-Civic, and (4) Economic Needs.³ While the mere framework of classification as given here is too general to be very suggestive, it would appear to be, in fact, exhaustive.

Few indeed, however, were the institutions which chose to abandon the traditional organization of educational experiences according to subject matter classification. Very few educators

¹Ibid.

²Ibid.

³Commission on Secondary School Curriculum, Science in General Education, p. 27. New York: D. Appleton-Century Co., 1938.

realized that the subject matter division is not a reflection of nature and reality but a device for dealing with complex material. Nor is it easy to abandon an established device of this sort even when no special significance is attached to it. Vested interest, the need for maintenance of academic respectability by providing specialized training for professional persons, and the great availability of subject matter specialists for college teaching, have effectively prevented widespread abandonment of subject-departmental curriculum organization. If education is to consist of fruitful experiences for the new college clientele--if it is to realize adequately its social goal--a method must be devised which will permit the needs of students to be met within the departmental organization characteristic of existing institutions. A way must be found to permit each specialist to contribute to the students the knowledge or skill possessed by him which will be useful to the student in solving his problem. While it is probably true that the departmental organization of colleges and universities is not appropriate to the educational task which confronts them, it is not true that the departmental organization precludes effective learning. This is the case only in departments which continue to assume that their major function is to train subject matter specialists, and that subject matter specialists are most effectively trained by teaching formidable bodies of organized fact.

It is the purpose of this study to describe, and, so far as possible, to substantiate, a method by which departmentally organized courses may contribute effectively to the needs of students. A course in inorganic chemistry adapted to the needs of agriculture students will be examined intensively in order to do this. Before taking up this task, however, it seems desirable to examine certain of the assumptions in the needs approach in order to make clear certain of its limitations and its relation to the social order.

CHAPTER II

SOME ASSUMPTIONS OF THE NEEDS APPROACH

Student Welfare is the Focus of Educational Effort

This assumption has often been attacked on the grounds that the school has an obligation to society, as well as to the student. Some critics have even maintained that the school, being a social institution, is obligated to society alone. Russell and Judd in The American School System¹ appear to take this viewpoint, stating that the school exists, not because people wish to be educated, but because democracy needs an educated electorate; not because people wish to enter lucrative professions, but because society has need of adequately trained professional personnel.

This viewpoint is occasionally countered by pointing out that fundamentally, no conflict exists, because what is best for the individual must be best for a state composed of individuals. This seems faulty reasoning. The world has not yet completed its latest demonstration that the interest of individuals may not coincide with that of state policy, but so spectacular has the first part of the demonstration been--so novel and impressive the use of visual aids, sound effects, and lethal chambers--that one must be skeptical indeed to remain unconvinced. It is clear that the needs of a young person--often of large groups of young persons--are in opposition to those which most persons would feel were those of society. Indeed, some very pressing needs of contemporary youth in our culture might be met by the following courses:

1. Technics of draft evasion.
2. The discovery and maintenance of black markets.
3. Imitative penmanship and the American banking system.
4. Applied toxicology.

Why do such courses not exist? Is it because the first obligation of the school is to the welfare of society rather than to the student? Is it because no student has a real need to stay

¹Russell and Judd, op. cit., pp. 10-12.

out of the army, buy a new set of tires, forge a check, or murder? The former reason does not adequately describe the dynamics. The latter seems rather naive; one refrains from murder because it is wrong, or unsafe, not because it is never profitable. These courses are not found in schools because, whether morally obligated to society or not, schools are subject to social pressure, and because their presence in the curriculum would destroy the symbolic value of education even if they enhanced its usefulness. From the viewpoint of this study they should not be in the curriculum, not because they do not meet real needs or because society rejects such needs, but because they obviously interfere with the needs of other persons, who do not lose equity because they are not students. A needs approach to curriculum must take into account the needs of all persons involved by any behaviour taught. This may appear to be a prolix way of restating the doctrine of direct responsibility to society but the implications are somewhat different. The needs approach as here conceived would permit the teaching of evolutionary concepts in Mississippi, if the teacher felt able to evade prosecution, even though this is contrary to statute. It would not permit certain courses which are socially permissible and highly marketable--courses in advertising which teach students merely how to frighten or coerce persons into purchasing articles for which they have felt no previous need, or courses in athletics which diverted to the purposes of spectacle and profit the facilities needed by the students for their own growth and development, would not, for example be authorized.

Learning Influences Behaviour

This assumption is obviously true if, by learning, one means the development of technics or familiarization with facts whose use is already envisaged by the learner. Learning to type influences the behaviour of a person who wants to type; learning which railroad runs from Chicago to Evansville influences the behaviour of a person who wishes to make the trip. But traditional educational practice is predicated on the assumption that, if a person is only given the relevant facts, he will seek to make a rational decision on issues involving them. This doctrine is basic to a common misinterpretation of "the scientific attitude" as a fosterable approach to problems, and to the very widespread

belief that the democratic, and therefore the morally defensible, approach to controversial problems is to present all the facts on all sides so that the student can make up his own mind.

Newer educational practice continues, of course, to accept the principle that learning influences behaviour, but is much more cautious in its confidence as to the distance at which factual learning can make itself felt. It is now known that effective transfer of training between learning situations occurs only when the situations are more similar than they usually are. It is accepted by the adherents of organismic psychology that learning is structured and must appear in relation to the situation in which it is to be effective. The mind, it is felt, may serve as an arsenal, but never as an attic.

The Basic Faith in Insight and Rational Use of
Comprehended Fact in Determining Choices
of Behaviour Remains the Cornerstone
of Educational Planning

If it is not true that people tend to act in accord with what they understand and believe to be true, then the technics which have been used in this study will not adapt a course to the needs of students, though other technics might yet do so. In all honesty, however, it must be granted that knowledge and insight loom smaller and smaller among the effective methods by which human behaviour is modified. That, in the absence of other factors, they are the determinants cannot be questioned. But other factors are seldom absent. The producer of cinemas, the advertiser, the columnist, are more effective determiners of behaviour, not only than education, but than the events of one's own life. Effective propaganda is never factual, but it changes behaviours and attitudes.

The psychoanalysts have demonstrated that the roots of human attitudes lie in the emotional connotations of experiences long since passed from intellectual relevance. Rogers¹ and the school of non-directive counseling charge, in effect, that despite their recognition of irrational bases of behaviour, the analysts depend on forced intellectual acceptance of reality for modification of behaviour, and that this attempt to attain control through

¹Carl R. Rogers, Counseling and Psychotherapy, pp. 27-51. Boston: Houghton Mifflin Co., 1942.

the relatively feeble factor of the intellect is the reason why psychoanalysis is so long and painful. Each of us has known persons who clung tenaciously to beliefs in the inferiority of a people or race despite their own admission that no shred of evidence supported them and much opposed them. Each of us, in fact, uses technics other than the objective presentation of fact when it is imperative to our own welfare that we elicit a particular response from someone who controls our fate on a particular issue. Arnold¹ has cited evidence that opponents in a political discussion will usually select from an impartial presentation only those facts which favor their position, and ignore others.

Since much more effective technics than the objective presentation of relevant fact in changing human behaviour may be developed by scientific research, and since the former technic is the only one which preserves the right of the individual to determine his own destiny, it follows that democracy is seriously threatened by the calculated application of technics designed to move men irrationally. Such scientific methods of propaganda are a different thing indeed from the empirical special pleading of our picturesque earlier politicians and robber barons. The neurotic personality of our time, and Horney's, is especially susceptible to them. But we cannot reject the premises because the conclusion is painful. Who in 1945, can answer positively the questions which Lincoln raised at Gettysburg?

The Objectives of a Course Are Determined by the
Changes Which It Is Intended to Produce in
Students, Rather than by the Subject
Matter Peculiar to the Department
in which It Is Offered

Nothing in the foregoing statement applies specifically to science courses. That this is so illustrates a characteristic relationship of subject matter to student need. The fact that a particular course is a science course determines what tools are available to serve students--scientific information, insights, and method. It does not determine what needs to be done. The objectives of the course are derived by scrutiny of the present situation of students, and inference as to what will probably be re-

¹Thurman Arnold, The Folklore of Capitalism, pp. 100-07. New Haven: Yale University Press, 1937.

quired of them in the future. No one could maintain that the same learning experiences will be optimal for all students, since each is different in background, present situation, and goal. Nor can one maintain that this unique and characteristic pattern is basically altered by the student's passage from one classroom to another. Rather, each classroom provides the student with opportunity to derive from a particular specialty information or skills which might be used to solve the same problems.

Science courses are thus regarded as flexible situations in which the materials and learnings thought in our culture to be appropriate to the sciences may be used to promote growth toward objectives in a sense unique for each student, rather than as fixed matrices from which students must select learnings which they can use. In a course in chemistry, for example, one will study the behaviour of matter in its various forms as a means of contributing the peculiar values of this sort of insight to the effectiveness of students in reaching their goals, but one's purpose, and hence one's selection of learning experience, is determined by the goals which students are to reach--goals which could have been stated without the specific knowledge that a chemistry course was to be offered.

Learnings are Chiefly Useful in Situations Similar
to That in which the Learning Occurred

In a course adapted to student need, effort is made to select only learning experiences which relate to problems which the student can accept as valid. No material is included simply because it occupies a prominent position in the logical structure of the traditional subject-matter edifice. The facts and principles of the field are used as tools. In a curriculum made up of courses adapted to student needs, the science course differs from other courses in the facts and principles from which selection may be made. It does not differ in objectives, except in so far as students have needs which may be met completely by a knowledge of science alone, or needs to which science can contribute nothing. In practice, few such needs are encountered.

PART TWO

AN EXAMPLE OF THE DEVELOPMENT OF A SCIENCE COURSE
ADAPTED TO THE NEEDS OF STUDENTS

CHAPTER III

FACTORS ANTECEDENT TO THE PROBLEM

The Situation in Which the Course Was Developed

At the opening of the academic year 1941-42, the Department of Chemistry at Oklahoma A & M College sponsored three simultaneous programs of research in the teaching of chemistry. The chairman of the department, Otto M. Smith, had for many years been actively interested in the improvement of science teaching. At the time of the opening of the research, he served as chairman of the committee on testing of the American Chemical Society and as an author of the American Council on Education Co-operative General Chemistry Test for College Students which is issued annually, and was awaiting publication of a laboratory manual of exercises on a semi-micro scale of which he was author jointly with two other members of the department.

The three investigations launched in 1941 were: (1) A comparative study of three methods of laboratory instruction, (2) a study designed to make the course in chemistry offered to students of home economics more effective, and (3) the development of a course in inorganic chemistry adapted to the needs of agriculture students. These studies corresponded to the manner in which the course offering at Oklahoma A & M College was organized, as the full-year freshman chemistry offering was divided into three courses: (1) a conventional chemistry course designed for students in the schools of arts and sciences and engineering, (2) a course offered especially for students in the school of home economics, and (3) a course offered especially for students in the school of agriculture. Both these latter courses were essentially of the conventional sort, adaptation having been confined to the introduction of certain laboratory experiments and the selection from topics ordinarily found in first-year chemistry --those considered appropriate to the mental level of students of home economics and agriculture, since such students were, in the folklore of the institution, regarded as less capable.

In addition to these three two-semester offerings, the college offered an intensive and highly theoretical one-semester course in inorganic chemistry which was available to those students who had made the highest grades on the Iowa Chemistry placement or aptitude test, regardless of the school in which they were enrolled.

Oklahoma A & M College is one of the two large state institutions of approximately equal size, the University of Oklahoma at Norman, Oklahoma being the other. So far as may be superficially judged, the division of state-supported higher education between the two institutions is in accord with an eminently Prussian class pattern. The institution at Norman, while offering many professional curricula, is largely a liberal arts institution, while the college at Stillwater is chiefly a technical school. Since the offerings at Stillwater, even in such areas as art and music are quite complete, the difference in the two schools must chiefly be one of status. Students at Oklahoma A & M College commonly regard those at Norman as being snobbish, and leading a country-club sort of life, which is usually a sign of defensive feeling.

The enrollment at Oklahoma A & M College is usually given as about 6,000, but since this includes all persons coming to the campus during the year to study in short courses or institutes, the figure for full-time students would be closer to 2,500. It is located in a city of some 10,000 persons, about 70 miles from either Oklahoma City or Tulsa, but not on any main highway. Nor is Stillwater on any through railways; transportation into the town, at best inconvenient, became a serious problem during the period of gasoline rationing. Stillwater appears relatively primitive for its size to some persons accustomed to small towns in other parts of the country. It has no satisfactory hotel or restaurant, and no attractive architecture. The range of income is small; the standard of living among the white residents being lower-middle class for the most part, with a small white slum area near the tracks on the east side of town. About 20 per cent of the population is Negro; with respect to these, Southern mores prevail. Education in Oklahoma is segregated at all levels. Recreational facilities for white residents are superior; in addition to the usual number of cinemas, there is an excellent city library and a superb collection of phonograph records which any resident

may borrow. The college usually sponsors an allied arts program of high quality during the school year.

Stillwater has many churches. There is no synagogue, but there is a Roman Catholic Church and a host of Protestant Churches. The Episcopal Church is small; most of the community belong to the more highly reformed Protestant sects. Members of the chemistry department staff were given to understand that attendance at the church of their choice would probably do them good, but were not under pressure to act on this. The state of Oklahoma is dry, except for the sale of 3.2 per cent beer. Divorce, however, is a frequent topic of conversation, and appears to be fully accepted into the cultural pattern.

Characteristics of the Students

The student body of the college is by no means purely rural. More students come from Stillwater itself, Oklahoma City, or Tulsa, than from any other one place, as might be expected. Few of these enter the school of agriculture. A colorful minority group which quite frequently contributes members to the school of agriculture consists of Jewish students from eastern cities who choose to come to Stillwater because the community is inexpensive to live in; the college has a good technical reputation, and anti-Semitism, though present and growing, is only moderately intense.

Except for these urban people, the students of agriculture come from a fairly uniform cultural pattern, which gives them certain common characteristics, though the range of personality among them is complete. Of 16 students in a group which explored the teaching method used in the study, 8 were born in Oklahoma towns ranging in population from 1,000 persons to 40,000 persons, 5 in villages smaller than 1,000, and 3 were resident in New York City. None of these students made their home in Oklahoma City or Tulsa, and only 2 of the 8 who were born in these medium-sized towns actually lived in town--they were the 2 who were born in the two largest of the towns. The remainder lived on farms outside of town.

Two of the boys from New York, 3 of the town-born boys, and 2 of those born in villages hoped to continue in college to get a Master's Degree. All the rest hoped to get a Bachelor's Degree. Only 5 of the 16 boys planned to become farmers, and of

these, only 1 planned to take an advanced degree. Only 1 other boy hoped to enter private enterprise; he wished to become a florist, and to take a Master's Degree. The remainder hoped to become government employees, primarily specialists in the Department of Agriculture, but some as teachers of vocational agriculture under the Smith-Hughes Act.

The pattern of amusements enjoyed by the various boys is too varied for any generalizations as to number to be made. In general, the pattern was normal. Most of the boys liked to read though no serious reading was done, except technical books on agriculture, and Time Magazine. One boy enjoyed the Atlantic Monthly. The radio, the cinema, dancing, sports, dating, were all enjoyed. The important generalization brought out by these data is simply that the recreational pattern of the boys was characteristically American rather than rural. Some of these statements concerning their recreation are well worth quoting in the students' words:

I enjoy playing baseball, football, and any outdoor sports. I enjoy reading such valuable reading material as Time, Life, and occasionally The Atlantic Monthly. I enjoy the movies dealing with the life of the lower east side. These movies are realistic, and tend to bring out the social disorder in many of our large cities.

I like to sing cowboy songs and yodel, and accompany myself on a guitar. This is one of my greatest enjoyments.

I go to movies, sometimes because I am especially interested in a certain film, but mostly because it is on Saturday night. I especially take interest in trying to be able to recognize popular orchestra leaders when I hear them on the radio. I like Life magazine and read it quite a bit. I like to get into a bull session with boys my own age.

I like to read the following materials: Reader's Digest, Extension Division pamphlets pertaining to my major, daily newspaper, psychology books, stories and books of famous people, and sometimes a fiction book.

I do not go to the movies regularly, but if I think I will like a show and if I have the money, I go see it. I like several physical sports, such as basketball, football, horse shoe table tennis, swimming and others. I do not consider myself good at any of these, but I enjoy seeing the games played, or trying to play myself. I also like to wrestle, but I think it is a dangerous sport and I don't often engage in it.

I also like playing such games as cards, dominoes, &c. I like to try to draw or paint pictures. I have had very little instruction in artistry, but I like it.

You asked about my leisure time. When I don't have anything to do, I like to be in a social group. Reading and movies are not my first interest. I like to be with people,

either at dances, parties, or other functions where a good time is to be had. If this isn't possible, I like to be alone and in a quiet place where I can do lots of thinking.

I also like to travel on ships. The main reason for this is because of the many people of different types and classes that travel on ships.

Reading any good, clean, worthwhile stories.

My main leisure time activities are not very suitable for class discussion but I try to enjoy all activities in which I take part.

The group of 16 boys which yielded this information was not representative of the students in the School of Agriculture, but could probably be inferred to be much more verbal, and more aggressive and secure intellectually than the norm. The basis of this inference is the recruitment of the group as volunteers for the new, exploratory program in which the technics for the needs-centered course were developed. Highly conventional or timorous persons would not have been likely to consent to participate in such a group, although an attempt was made to include persons who were not regarded as intellectually gifted or academically superior. The group enrolled in the full year experimental course were representative of the students of agriculture as a whole, since all such students were obliged to take chemistry, and the persons who chose to take the course at eleven in the morning found themselves in the experimental group. Some of their characteristics will now be examined. Of 68 students who submitted information sheets, 5 were born outside the state in communities having less than 1,000 population or on farms, 4 were born outside the state in cities having more than 1,000 population, 4 were born in Oklahoma City or Tulsa. Twenty-seven students were born in the state on farms or in communities having less than 1,000 persons; a precisely equal number were born in towns within the state, exclusive of the two major cities, having populations greater than 1,000. In Table 1 these groups are labeled A through E respectively. Some of the data are uncertain in that several students indicated that they planned to enter either farming or government service, or both consecutively, while several interpreted the phrase "vocational objective" to mean "college course major" or some similar concept. In the former case, the author sought to classify the student properly according to his personal acquaintance with him, while in the latter, no data were used. It is also not clear how many of the students who classified them-

selves as town or community dwellers actually engaged in farming, and so should have been included in Stub 2. Farming is here used to include ranching or poultry raising, that is, any kind of agricultural production for profit, either as owner or for hire to a private owner. Government service includes teaching of vocational agriculture, county agency, Department of Agriculture, technician, and other types of public employment. The professions mentioned were entomology and veterinary medicine.

TABLE 1

FARM BACKGROUND AND VOCATIONAL GOAL OF STUDENTS IN
NEEDS-CENTERED COURSE, ACCORDING TO PLACE OF BIRTH

	A ^a	B ^b	C ^c	D ^d	E ^e
Number of Students in Each Group.	5	4	4	27	28
Number Spending Most of Life on Farm	5	3	1	18	13
Number Planning to Continue as Private Producer in Agriculture . . .	3	2	3	16	15
Number Planning to Enter Government Service	0	0	0	9	8
Number Planning to Enter a Profession	0	0	0	0	0

^aIn village of less than 1,000 inhabitants or on farms outside Oklahoma.

^bIn cities of more than 1,000 inhabitants outside Oklahoma.

^cIn Oklahoma City or Tulsa.

^dIn villages of less than 1,000 inhabitants or on farms in Oklahoma.

^eIn cities in Oklahoma of more than 1,000 inhabitants, except Tulsa and Oklahoma City.

The desire for graduate study evinced by the small exploratory group is scarcely shown here. The 3 students seeking to enter the professions hope to obtain appropriate doctorates, and 3 others from the total group would like to obtain the Master's Degree. One student specifically states that he plans to take but two years of work. The remainder all state that they wish to finish the four-year course, or that they wish to continue until

drafted. There appears to be no difference in personal objective between these two statements.

Certain implications seem to stand out from these data. These may be listed as follows:

1. Although Oklahoma A & M College has an internationally known school of agriculture, it draws its students primarily from its own state. Several of the few students born outside Oklahoma had lived there since childhood.
2. Girls are negligibly represented in the School of Agriculture, and students of predominantly urban background are few.
3. Students are about evenly divided between villages and fair sized towns as their place of origin.
4. The vocational purpose of the students is well and uniformly established. Even during wartime the students do not doubt that they will earn their living ultimately through agriculture or a related field.
5. The students feel the threat of personal involvement in the war much more realistically than they did nine months earlier.

The leisure activities listed by members of the group show much less originality and resource than those listed by the exploratory group. Thirteen of the 68 students gave no answer to the question concerning leisure activities. Of the remaining 55, many merely listed their interests without comments, or answered in a single phrase. Motion pictures were the most nearly universal interest, with baseball, hunting, and fishing also quite common. Some of the more revealing responses are given below, in the students' own words.

I would like to learn some photography. I enjoy to read books of knowledge and travel with an occasional best novel thrown in. I enjoy a good show about once a week.

About three movies a month. I prefer subtle and heavy drama movies. Also slap-stick comedy such as that of Bud Abbot and Lou Costello. I like to play tennis, ride horseback and train colts.

I enjoy stamp collecting and like to work on my own insect collection.

I like movies that have a thrill and a laugh to them. Anything from the "Three Stooges" to a cowboy show. I don't have any particular fondness for love pictures. I don't read much but I enjoy all outdoor sports. [Student 18 years 9 months old]

What little leisure time I get is used in many various forms. Since I work at the Beef Barn, I spend most of my leisure time working, such as trimming hoofs, washing steers, roping, doing chores and etc.

I enjoy play some kinds of games and good around to pretty scenery.

To go on a hike or a walk in the open air.

I enjoy playing base or soft ball go the movies about 1st a week and like to read books adventure, romance, mystery, most any poplar book.

My main hobby is sports. But I do not intend to carry them on through life to a great extent. . . . [I] have a good chance of play professional ball some day however I need a greater background than this because you have to have a future after 35 years. . . . I spend a great deal of time around the stockyards in Okla. City, where you see all types of cattle and get acquainted with all types of buying.

I like to rope calves, good movies, good music, to dance, and all sorts of sports.

Attend social events because it helps you to learn more about people as well as get acquainted with new friends.

These examples of leisure interests reveal several interesting characteristics, among which are:

1. Relationship of avocation to vocation is often quite close.--These boys really enjoy farming. It has not become for them the sterile and inexpressive activity which working for a living usually is for lower-middle class persons. Farming certainly entails much drudgery, but it appears to be an occupation in which the worker can keep constantly in view the significance of his acts for the total production process. It is not mechanistic, repetitive, and boring, in the way that a job on an assembly line is. It should be borne in mind, of course, that, although the standard of living of these students is not higher than that characteristic of the lower-middle class, they are largely from families near the top of this somewhat underprivileged occupational group. Persons in this position ordinarily enjoy their work, no matter what it is.

2. Activities permitting self-expression or self-interpretation are lacking.--These boys do not sing, or draw, or write. They participate only in competitive sports, or hunting and fishing.

3. Amusements are highly commercialized.--A naïve belief that this is not the case sometimes dominates our picture of rural life. We tend to believe that creative activities--square dances, crafts, and so forth--predominate. They do not. Motion pictures and spectator sports are dominant here as elsewhere in the American culture.

4. Verbal abilities are very low.--Many of the students appear to be unable to write a satisfactory answer to a written

question. Verbal expression is not used much in social intercourse within this group of people; not only is it likely to exhibit quaint errors of construction, or when written, of spelling and punctuation, but precise expression of complex ideas is not possible and does not occur. Reading of the kinds of documents likely to develop insights, or critical or abstract conversation, has no place in the culture.

5. There is not the slightest interest in social problems, or awareness of the structure or dynamics of the society of which these students are a part.--This is particularly strange since a quarter of the total group plans to make a life work of some kind of government service, and since all are threatened by the war, which is surely a social phenomenon of a conspicuous kind. Anxiety about being drafted is almost universal, but nobody feels any curiosity about the significance of the war, its background, or the army as a social institution. Indeed, the students appear to be unaware that any systematic investigation of social institutions or relations is possible.

The Student in His Culture

While the students we have been examining lack verbal ability and social and psychological insight, they nevertheless face problems which cannot be solved without them. They therefore frequently become victims of processes which they do not understand, and which can be controlled only by techniques which they either do not know, or would disapprove too strongly to use. Like everyone else, the student of agriculture behaves most effectively in situations with which he has had most experience. But the Oklahoma "Aggie" boy has been reared in a folklore which limits him in utilizing his experience. This condition is common-place enough throughout America, and is by no means peculiar to Oklahoma, but its cultural homogeneity, especially in the rural portions, tends to emphasize the difficulties. Few persons have opportunity for more meaningful experiences than the members of the Oklahoma farm culture, but young persons scarcely dare to interpret these accurately. The Oklahoma "Aggie" boy, more than his contemporaries in many parts of the world, is taught to regard his environment as fundamentally simple and capable of being described in terms of black and white. He learns to make simple, inviolable generalizations which reduce to a moral principle areas

of human conflict of greatest complexity. That these generalizations are almost useless as bases for prediction or control is attributed to the regrettable difference between the way people act and the way they ought to act. Human tragedy results only from the failure of men to live up to the very simple rules which govern their conduct in much the same way that chemical laws are thought to govern chemical reactions rather than to describe them. Persons who believe this commonly do not attempt to control their environment by effective political technics, and are usually suspicious of people who do.

Examples of this attitude may be found in almost every aspect of human living. Questions of economics are clear and simple--clear and simple as they can only be to a boy who has worked fourteen hours a day in a field for a standard of living not far above survival, rather than organize with other farmers to improve his condition; who has carefully reared stock and taken prizes of hundreds of dollars while still in his early teens at competitions sponsored by wealthy oil magnates. Questions of ethics and of the nature of authority are clear and simple--clear and simple as they can be only to a boy who has been spanked each time he diverged seriously from accepted standards of behaviour, and whose greater maturity has been recognized by the high school only by the substitution of a paddle for the calloused palm. Questions of aesthetics are clear and simple--clear and simple as they can be only to a boy whose home is surrounded by many acres of land but has no garden, who has access to no library, and who sees few pictures except dime-store reproductions. Questions of democracy are clear and simple to a boy who has been told often that one man is as good as another, but who has seldom if ever seen opportunities provided for all persons concerned in a situation to participate in determining policy about it--at home, in school or on jobs.

The concepts which the boy holds cannot be synthesized into a useful pattern of cause and effect relations. Do the old friends of his family lose their farm after years of backbreaking labor and join the forlorn migration to the San Joaquin Valley? Some people have bad luck, and some are unscrupulous, but thrift and industry will surely lead to the realization of the American dream of a vine-covered cottage with a Delco unit and an electric refrigerator, under the blessed aegis of free private enterprise.

Does his younger brother commit even more spectacular delinquencies before his pants have quit stinging from his last correction? Then take him across your knee again, and this time make sure he feels it--a kid has to learn to do what he's told. Does the student feel actual enjoyment in looking at the exhibits or walking in the gardens of the Philbrook Museum when he goes to Tulsa? Yes, but these are things for museums, to be gathered together as a source of civic pride, not to be enjoyed as a part of daily life.

These examples, of course, produce a greatly oversimplified picture, but they do represent some salient characteristics of an outlook common among students in the School of Agriculture at Oklahoma A & M College. Naturally, there are among these persons of profound insight and deep understanding. But even they usually believe that the tragic world in which they live skillfully and fruitfully is somehow the result of human weakness and malevolence; that the world, fundamentally, may be explained in terms of simple, permanent, and discrete truths, and that the complex behaviour which makes it possible for them to live more richly than certain of their fellows is not above reproach, since it is inconsistent with the religious or economic concepts which they hold in common with their less gifted confrères. Nor have they the semantic sophistication to perceive that this conflict exists and to understand it. The "Aggie" boy has not learned to differentiate between his language and the experience which it describes. It does not occur to him that concepts of which he speaks may not refer to anything whatever in the external world. His communication is thus limited to experiences on so low a level of abstraction as to be certain to find a referent in the experience of any listener, or to meaningless but familiar economic and theological noises. The important subjective characteristics of his life--how he feels, how he fits into his community, the reasons why he gets into trouble occasionally, why he may fail to do his work, or fight with his best friend--are all nameless and inarticulated. If he speaks of them, it is in conventional terms which promote no understanding--terms like "I guess I'm just lazy," or "Paw and I can't get along." This is not the result of an effort to evade a painful problem, but a failure to recognize the existence and relevance of factors resulting from psychological or social rather than objective physical circumstances. The boy then cannot make himself

understood as a total personality, even to himself. Emotional maladjustment is probably no more common here than elsewhere, but when it does occur it is extremely difficult for the boy or his parents or friends to do anything about it. A boy whose work is being hampered by schizoid trends or anxiety neurosis will probably incur disciplinary action rather than therapy; boys exhibiting a truculence born of deep and painful feelings of insecurity, of lack of affection or of rejection by their peers, are ignored as long as possible and then suppressed. And they themselves feel such treatment to be entirely appropriate, because such difficulties are not recognized by the Oklahoma folklore.

Responsibilities and Limitations Imposed on the Course by Oklahoma A & M College as a Situation

It is a commonplace that, in developing a course to be offered at an institution, however fully that course may be focused on the needs of the students taking it, the situation in which the course is to be offered will partially determine its technics and content and will limit the possibility as to what might be done. Sufficient attention has been given to the situation at Stillwater, and to certain of the characteristics of the students, that the reader can doubtless anticipate what some of these limitations were. It seems desirable, however, to structure the situation more adequately by enumerating certain of them here.

Students were Lacking in Verbal Skills

The conspicuously small role played by complex verbal communication in the lives of the Agriculture students has been pointed out. The implications of this condition are clear; yet it must be admitted that the least satisfactorily met of all problems confronting the instructor and students in developing the course was this one. There are very few (one is tempted to say that there are no) satisfactory non-verbal experiences adaptable to the classroom which will provide relatively complete insight into problems which science can help solve on the level at which college students need to solve them. The best possible solutions of actual problems requires a lot of information, and even more synthesis of information into a complex pattern. Neither the facts nor the relationships are usually capable of being derived from our experience, and only verbal communication is specific

enough to augment that experience with precision. A conflict inevitably arises between the best which a person is capable of doing intellectually and the intellectual requirements which a situation actually imposes on him, even if no teacher is intentionally making the problem more difficult for the sake of mental discipline.

Nor can the responsibility for this situation be laid entirely to the disparity between problems and the people who are faced with them. The instructor was also often to blame. The experiences which are thought suitable to the development of college teachers are largely experiences which emphasize verbal communication and deprecate naive experience. The college teacher who can arrange effective experiences which bear their own significance, without verbal interpretation, is rare; even with the best will in the world, he will often lack sensitivity to his opportunities. Therefore, while fully aware that the chemistry course for agriculture students must be much less verbal than the usual college chemistry course if it is to meet most effectively the needs of the students for whom it was designed, the instructor often failed to provide suitably non-verbal experiences, and some of the learning experiences were less effective than they should have been for this reason.

Community Offered Only the Most Limited Urban Resources

In a chemistry course offered in an industrial location, some instructors use field trips to chemical plants, or plants in which chemical processes may be observed to provide direct, relatively non-verbal experiences for students. Stillwater possesses no such plants. The only obvious goal of such a trip was the city water plant, which had been closed to the college by the time the experimental group was launched due to the need which the community felt to regard itself as a military objective. Had war conditions not existed, it might also have been possible to organize a field trip to one of the neighboring cities, but the college offered little support for such a plan at best. Without gasoline for student cars it would have been very difficult, even if admission could have been secured.

Difference Between Ideology of Course and Prevailing Attitude of College Staff Toward Students

Wherever a procedure is introduced into an institution which is based on assumptions different from those which the institution regards as basic to it, hostilities may be aroused. Administrative skill and tact can usually avert these, but the skill and tact themselves frequently consist in adopting indirect procedures or compromises which are in fact limitations on the accomplishments sought. There were several fundamental differences in the attitudes which were responsible for the conduct of the experimental program, and those prevailing among the institutional staff. Among the most important of these attitudes adopted in the devising of the experimental program but not universally accepted in the institution were:

The dignity of student personality requires that students be coerced as little as possible, and that they be given an opportunity to participate in the making of all choices affecting them.--Customary policy in dealing with students was the making of minute assignments, use of extraneous and frequently degrading types of motivation such as threatening students with tests, ridiculing them for laziness, and other familiar patterns. The rejection of such technics in the experimental program was potentially a threat to such staff members as depended on their use for their own feeling of security. Nor could the student grow as freely when compelled to make constant readjustment from the experimental situation in which he was treated as an adult, perhaps for the first time, to other situations in which adult behaviour would have been regarded as an impertinence.

It is important that students be happy and comfortable in a situation, although it is not always possible. They shall not be denied such happiness except, with their consent, in assisting them to relinquish immature adjustments.--Obviously, the experimental program was not the only course in the college in which this attitude was held. It was probably a prevailing attitude. There were, as always, however, certain members of the staff who derived satisfaction from the exercise of authority as such; who felt that the creation of a disciplinary situation was a part of their duty; and to whom the attitude taken in the experimental program was actually a kind of castration threat. It is perhaps worthwhile to emphasize that such issues are quite real. One

often finds that members of a professional group feel that mutual understanding will eliminate friction and lead to co-operation. This is not true unless the persons who understand each other also share objectives. If they do not, mutual understanding will increase hostility.

Many of the problems and frustrations incident to everyday life in the world are due to the inappropriate nature of our social and economic arrangements.--Fundamental criticism of economic and social conditions is not common at Oklahoma A & M College. During the time that the experiment took place a common subject of gossip among the staff members was a promising young member of the department of history whose contract had not been renewed. It was commonly believed that the reason he had not been retained on the staff was the research which he had been doing into the methods used to sell Liberty Bonds during the First World War. The sentences of several Oklahoma communists to prison on the grounds that membership in the Communist Party violated a state criminal syndicalism law had not yet been set aside by the State Supreme Court. The Governor, Phillips, had made belligerent statements forbidding the employment of teachers who had joined the American Federation of Teachers in schools of the state. There can be little doubt that most of the people of the state, and many of the staff of the college, felt these various repressive actions to be appropriate, but in any case, realistic examination of the social structure was not thereby encouraged. In particular, a science teacher who regarded social problems as influencing his teaching responsibility would be felt to be going out of his way to get into trouble.

The culture of Oklahoma had many values leading to growth of its citizenry, and many defects which hampered them. Realistic study of the culture is the most effective way to support the former and repair the latter.--Many Oklahoma citizens characteristically react to any indication that their culture may be criticized with strong feelings of guilt and with aggression. At the time the experiment was carried on, it was still impossible to discuss the literary merits of Steinbeck's The Grapes of Wrath with many persons who had read it. They had become fixated on the idea that the book had pictured some Oklahoma people as poor and uneducated, and would not penetrate beyond these concepts. The fact that the book had been highly sympathetic to these people;

that it had not pictured them as representative of middle-class standards in Oklahoma; that it was of good literary quality; and that Life magazine had documented,¹ in a popular format, the existence of the conditions described, was either beside the point or added insult to injury. Both staff members and students share this chauvinistic attitude quite fully, and tend to resist objective examination of the state's cultural patterns, even though there are many reasons why the conclusions of such examination might be, on the whole, favorable.

It is not to be inferred that the existence of the four potential conflicts of ideology just summarized, and of others less prominent and less frequently encountered, made work in these areas impossible and fruitless. On the contrary, if no conflict had existed, no opportunity for growth would have existed. It was, however, necessary to recognize the existence of these differences as factors limiting what might be done in the situation, and affecting one's choice of the means for doing it. No institution is free from these or similar limitations, and the fact that they existed adds support to the inference that courses may be adapted to student need in quite conservative institutions.

The Course Offering for Agriculture Students
at Oklahoma A & M College was Structured
Before the Beginning of the Experiment

In adapting a course to the needs of students, one can work most effectively in situations which allow the use of broad areas of subject matter. In a fully needs-centered curriculum, there would be no use of subject matter classification in the organization of learning experiences--the organization would be derived from the pattern of needs itself. It is more profitable to study a problem such as "How can I live so as to enjoy optimal health?" than a problem such as "How can chemistry help me to live as healthfully as possible?" The latter organization is often necessary in order to permit the curriculum to be adapted to needs in institutions already inflexibly organized into subject matter departments; indeed, a method by which this may be done is the sole concern of this thesis.

¹"These pictures prove facts in Grapes of Wrath," Life, VIII (February 19, 1940), 10-11.

At Oklahoma A & M College however, this antecedent structuring of the situation went further than would be encountered in a college simply because the institution had organized its offering by departments, since the offering in chemistry for agriculture students consisted of two separate courses. The first of these, on which the experiment was based, and which lasted two semesters, was a course in inorganic chemistry. The second was a one-semester course in organic chemistry whose subject matter had already been extensively revised to conform to the vocational objective of the students. At the outset of the experimental program it was decided to exclude this organic chemistry course from the experiment, since it was already functioning rather satisfactorily, and since including it would have prolonged the experiment beyond the length of time during which the college hoped to retain its students, the war having been in progress nine months. Since, however, those students hoping to complete their program at all would ultimately be required to take the organic chemistry course, it did not seem legitimate to include in the experimental program a study of problems whose solution would require chiefly the application of organic rather than inorganic chemistry. This provision resulted in fairly fundamental distortion of the experimental program, in a manner which will be clarified in the description of the program.

Inflexible Administrative Needs of the Laboratory

About a week's notice was needed by the laboratory stockroom to provide equipment and reagents for special experiments. It would not have been possible for them to provide separate materials for each student, even with considerable notice. It was not, therefore, possible to allow each student to develop an individual laboratory procedure in accord with his own conception of his problem, as would have been consistent with the organization of the course.

The Instructor Lacked Skill in Leadership of Group Rather than Individual Work

It will probably appear to the discerning reader that many useful opportunities for democratic planning and interaction were lost by maintaining operations on an individual rather than

a group basis, even though general procedures were determined by effective technics of self-government. The meaning of this will become clear as the operations of the course are described. The laboratory work could have been more effectively organized to this end by the method of Thelen,¹ and students working on similar problems could advantageously have worked as committees rather than as individuals, thus meeting more fully certain of the needs which will be outlined.

¹Herbert A. Thelen, "An Appraisal of Two Methods for Teaching Scientific Thinking in General Chemistry," pp. 1-370. Unpublished Doctoral dissertation, Department of Education, University of Chicago, 1944.

CHAPTER IV
SELECTION, DEFINITION, AND ORGANIZATION
OF STUDENT NEEDS

Classification of the Needs of Students

The pattern of student needs adopted for the organization of the inorganic chemistry course which formed the basis of the experiment is subjective in origin. The experience of the author in developing an experimental course in general chemistry at Fresno State College in 1941, and intensive study under the direction of Alvin C. Eurich at Stanford University resulted in the acceptance of the following as an inclusive statement of the needs of students:

1. To be in as good health as possible.
2. To be as attractive to other persons as possible.
3. To be an effective consumer of goods.
4. To support intelligently necessary public services.
5. To earn his living by a worthwhile contribution to the community.
6. To make effective use of leisure time.
7. To be able to defend himself against hostile environmental forces.
8. To participate effectively in the processes of democratic society.
9. To develop into an adult--mature, self-reliant in person-ality.

As indicated in Chapter II, there is nothing specifically chemical about this pattern of needs, nor is there anything in the pattern which is uniquely appropriate to the students for whom the course was designed. Instead, the pattern is so general that it is difficult to conceive of a normal person in Western culture who would not have needs in each of these areas. Of course, an almost infinite variety of ways exist in which a valid pattern of human needs may be stated; the problem is one of classification only. Area 7, for example, might have been subsumed under areas 1 and 8, or area 4 might have been included in area 8, or an entirely new classification might be written. It is im-

portant, however, that the classification when finally stated, be indeed a classification of needs, not of areas of human experience, or of cardinal principles of education, or even of objectives as such. Objectives, behaviorally stated, are derived from the pattern of needs, but some effort should be made to exclude objectives which do not clearly relate to the pattern.

The pattern is, however, too broad to be of value in planning learning experiences until broken down. Each area of need must be restated as specific behaviours which may be appropriate to each student. The behaviours chosen depend on the nature of the student and his culture, but not directly on the subject matter. The development of these behaviours then becomes the objective of the course, and inquiry into their development becomes a technique of evaluating student achievement.

The learning experiences arranged to contribute to growth toward the objectives are determined by the subject matter area in which the course is to be offered. In the case of the course here discussed, the area of subject matter is chemistry. Learning experiences for the course seek to use the materials of chemistry, rather than those of other subject matter fields. Some influence is even exerted by subject matter on the behaviours which the course seeks to develop, inasmuch as those which cannot be influenced by the materials of chemistry or the concomitant learnings determined by the course method are usually excluded from the course as inappropriate, even though real as needs. Thus, two possible specific behaviours included under area 5 of the general pattern might be:

1. The student needs to be able to choose a fertilizer of correct composition for various crops and soils.
2. The student needs to predict accurately fluctuations in the market price of agricultural produce.

The first of these needs is a valid objective of the chemistry course; the second is not. Many cases would be much less clear cut. Similarly, the objective--the student needs to be able to determine swiftly and accurately the amount of glucose in a physiological sample--is not valid for the course, provided the students are bona fide students of agriculture, even though the behaviour is appropriate to a chemistry course. The objective might become appropriate for an agriculture student of diabetic tendency who lived in an isolated area, but if so, it would be classified under area 1, not area 5.

Selection of Problems

The areas of need must, then, be broken into specific behavioral components before learning experiences may be selected for the course. This was done for the first area entirely by the instructor; succeeding areas were validated by an elected student committee as well. Lists of components were, of course, regarded as representative rather than exhaustive, and students were encouraged to select objectives of their own devising in any area they wished. This was not often done, but did occur.

In Chapter III, the section dealing with responsibilities and limitations imposed by the Oklahoma A & M College situation, it is mentioned (p. 34) that antecedent structuring of the offering for agriculture students compelled certain alterations in the experimental program which would not have been desirable had the program been developed in an unstructured situation. The factor involved was the existence of a course in organic chemistry, offered after the completion of the first year program, whose content had already been revised to relate it more closely to the study of agriculture. It was therefore deemed desirable by the faculty of the department that the experimental course seek to confine itself as closely as possible to the use of the subject matter of inorganic chemistry.

The needs included in the first two broad areas--health and personal appearance--require the application, primarily, of organic chemistry. They were therefore deleted from the course objectives. The remaining seven areas were broken down into selected, representative problem areas by the instructor, with the help of his committees. The breakdown finally used in the organization of learning experiences was as follows:

Areas 1 and 2. Deleted.

Area 3. The student needs to be an effective consumer of goods. The student needs:

- a. To choose suitable metalware for the plumbing system, kitchen utensils, and other metallic devices used in the home.
- b. To choose and care for glassware and window glass in the home.
- c. To choose suitable paints, varnishes, and lacquers to finish and protect the home and its contents.
- d. To choose china, earthenware, and enameled articles for use in the home.

- e. To choose and use wisely a fuel system for heating the home.
- f. To choose a suitable structural material for the home.
- g. To choose effective and safe antiseptics and disinfectants.
- h. To choose dentifrices, shaving soaps, and other aids to an attractive personal appearance.
- i. To use refrigeration facilities wisely and efficiently.

Area 4. The student needs to support intelligently necessary public services. The student needs:

- a. To support effective community procedures for the purification of water.
- b. To support effective rural or urban procedures for sewage disposal.
- c. To support effective community procedures for the detection of crime.
- d. To help conserve critical materials needed in the war effort.
- e. To support effective community procedures for the prevention and extinction of fires.
- f. To support the maintenance and enforcement of pure food and drug legislation.
- g. To use effectively the protection provided by official standards of weight and measurement.
- h. To support wise choices of materials for highway construction.

Area 5. The student needs to earn a living by a worthwhile contribution to the community.

- a. Dairy--the control of insect, fungus, or rodent pests. The student needs:
 - (1) To prevent the development of undesirable flavors and odors in dairy products.
 - (2) To control the production of foodstuffs dependent on bacterial action, such as buttermilk and cheese.
 - (3) To select for his dairy equipment metals which are durable under conditions of use, and which have no undesirable catalytic action.
 - (4) To handle milk and cream in such a way as to maintain optimum stability; to use effective technics of homogenization, or, conversely, churning, where appropriate.
 - (5) To prevent undesirable changes of bacterial or zymotic origin.
 - (6) To control factors affecting the quality of frozen dairy products.

- (7) To control insects which attack farm crops and produce.
- (8) To control fungi which attack farm crops and produce.
- (9) To use non-toxic agents to increase the effectiveness of insecticides and fungicides.

b. Soils. The student needs:

- (1) To control soil texture for most effective plant culture.
- (2) To plan his farm in accord with the relationship between cropping.
- (3) To provide essential soil constituents from external sources when natural processes cannot be expected to replace them.
- (4) To determine whether his soils contain all elements needed for the growth of plants, and to provide for possible deficiencies.
- (5) To use agricultural by-products of little market value as effective soil amendments.

Area 6. The student needs to make effective use of his leisure time. Among activities appropriate to the rural home and community, to which chemistry is rather directly related are:

- a. Photography.
- b. Home electrical work.
- c. Gardening.
- d. Cookery.
- e. Painting and sculpture.

Area 7. The student needs to defend himself against hostile forces in the environment. The student needs:

- a. To be able to extinguish an incendiary bomb.
- b. To defend himself against common war gases.
- c. To choose adequate defense against high explosives.

Area 8. The student needs to participate effectively in the processes of democratic society. The student needs:

- a. To be able to use libraries and other sources of public information effectively.
- b. To participate in the decisions affecting the policies of his group.
- c. To distinguish between reliable and unreliable authorities and sources.
- d. To distinguish semantically between meaningful and meaningless language.
- e. To act politically with understanding of the effect of technological advance on possible standards of living, and on the validity of current social and economic concepts.

- Area 9. The student needs to develop into an adult--a mature, self-reliant personality. The student needs:
- a. To be able to organize his work with a minimum of assistance from others, except experts called in to settle questions beyond his knowledge.
 - b. To complete undertaken responsibilities reliably.
 - c. To understand and accept his own personality, while seeking to improve its weaker traits.
 - d. To find his chief motivation in his personal goals, rather than extrinsically.
 - e. To demonstrate, by co-operation and tolerance, respect for the personalities of others.

Adaptation to the Experimental Situation

The foregoing statement consists of a list of behaviours, classified under each of seven broad areas of need, which the author would regard as among the appropriate objectives of a course in inorganic chemistry adapted to the needs of students in a school of agriculture. It is not a final statement of the course objectives, since this analysis was made before actual contact with the students had permitted information to be gathered about them, and before all the situational factors affecting course content and objectives were apparent.

It has already been mentioned that administrative necessity induced the omission of objectives related to the first two areas of need listed in the beginning of this chapter. Certain other deviations from the pattern of objectives which might have been followed, had a purely a priori establishment been practical, should also be noted here. It seems likewise desirable to indicate briefly the manner in which the objectives selected for the initial statement reflect the agricultural interest of the students.

No substantial difference is introduced into the conception of areas 3 and 4 by the vocational objective of the students. Essentially the same behaviours are held to demonstrate the capacity to be an effective consumer of goods, or to support intelligently necessary public services for rural as for urban students. There are, of course, certain differences in content--the study of water purification or sewage disposal would emphasize different technics for rural and urban groups--but the problems of living for the two groups, especially the material problems with which chemistry deals, are similar in these two areas. There appears,

indeed, to be much less contrast between rural and urban middle-class life than between middle-class and lower-class life in the same community, and college attendance is still primarily a middle-class folkway, in Oklahoma as elsewhere in the nation.

In area 5, however, variations appear. In "Characteristics of the Students" in Chapter III, it is established that the students in the School of Agriculture really do intend to earn their living in agricultural pursuits; no diversification of vocational objectives was sought in area 5. Since the educational interest of the student appeared to be dominated by his vocational purpose, much more emphasis was placed upon the objectives of area 5 than upon those of any other area. This might be inferred from the greater number of behaviours listed as objectives in area 5, their more technical character, and the division of the objectives into two subgroups. The consequences of this emphasis will become apparent in a subsequent description of the course methodology and experiences.

Areas 6 and 7 suffered a corresponding attrition. This likewise is a matter more appropriately discussed in connection with the detailed description of course content, but it should be noted here that the fate of these areas indicates that wide variations exist in the importance of the several broad areas of human need, and that the relative importance of these areas will also vary according to the special group of students for whom the course is being designed and the prevailing conditions of the social order. Thus, it does not seem that the contribution of chemistry to the recreation of a group of young men who plan to become farmers, ranchers, or agricultural technicians is comparable to its contribution to their vocational competence. This would very probably not be true if one were dealing with a group of young men and women whose vocational purposes were both varied and ill-defined. Of the possible leisure activities foreseen under area 6, however, only photography proved to have appeal for these students. Furthermore, in adapting a course to student need, it is imperative that one be constantly vigilant against assuming that, because an activity involves the use of chemical substances, a knowledge of chemistry is useful in undertaking it. Granite and oil colours are mixtures of chemicals, but neither Epstein or Picasso is a chemist. Effective use of leisure is undoubtedly a legitimate educational objective, but the chemistry

course seems to have much less to contribute to it than courses in the arts, the humanities, and athletics, especially for a group which neither cooks nor gardens for pleasure.

Area 7 is also rather unsatisfactory. It is probably an error in judgment, or at least in sense of proportion, to have included it. As stated, defense against hostile environmental forces should not be either so primal or so distinct a function as earning a living or growing up. Nor should most men feel that military attack is the most dangerous threat facing them; in the twentieth century war is merely the most formal symptom of a prevailing social and economic chaos--a hazard of transition in a culture which provides no security in peace either. The establishment of area 7, and particularly, the filling of it with purely military instances of defense against environmental hostility is probably a subtle inconsistency in the organization of student needs here presented. In 1942 however, such considerations seemed to have a peculiar urgency, and to differ so markedly in kind if not in purpose from sanitary precautions or crime prevention as to justify consideration as a separate area of human need. And, indeed, the need can scarcely be said to have abated.

Areas 8 and 9 differ from those preceeding them in the source of learning experiences available to lead to these objectives. This question will be more fully discussed in succeeding sections of the dissertation, in connection with content and evaluation. It is apparent from the specific needs listed that these areas alone are virtually independent of content. One may study about earning a living, or about the different things one buys. This kind of learning--facts, principles, and relationships dealing with one's problems of consumption, or the cultivation of crops--is the only direct aid a chemistry course can give to the solution of such problems. But learning about growing up does not directly help a person mature. Learning about the problems of democracy does help a person participate in the processes of democracy but such learnings are not an appropriate part of the content of a chemistry course, save as such problems may be related to natural resources, technological advance, or other issues involving the composition and behaviour of matter.

In area 5, the objectives imply that the student will learn something of the role of chemistry in farming. In area 8, it is not particularly important that the student learn much about

the role of chemistry in democracy. It is rather implied that the objectives of the course include the development, through the experiences offered by it, of a sense of one's own dignity and worth, and of that of others. Such an objective requires the provision of experiences quite foreign to the ordinary classroom. It requires the assumption by teacher and student of roles quite different from those to which each is likely to be accustomed. Its appraisal creates a need for practical technics of evaluation which do not yet exist.

Areas 8 and 9 are closely related. Growth is possible to the participants in a culture only to the extent that the culture is basically democratic. In an undemocratic society, maturity is possible only to those willing to play, patiently and with compromise, but steadily, the role of opposition. This is as valid for a classroom as for a nation, albeit for much smaller groups of people and for but a fragment of their total experience. The provision of areas 8 and 9 as objectives of the chemistry course is a binding commitment to the belief that the teacher is responsible for all the learning which goes on in his classroom, so far as it is within his power to control it, whether or not such learning arises from course content. The experience of being in a classroom, of playing the role of a student, is part of the curriculum. If the objectives of areas 8 and 9 are accepted, these experiences must be utilized to provide maximum development of the attitudes, insights, and values to which the policy of democracy commits us.

Areas 8 and 9, then, are not content areas in the same sense that the preceding ones are, and will not be related to chemistry subject matter. They determine method rather than content, and these together determine the quality and nature of learning experiences. Progress toward the objectives in these areas must be made in the course of studying problems arising in all other areas. There is no attempt to regard them as "chemistry" in any sense, but rather, as areas of experience to which any course designed to meet the needs of students should contribute through its procedures.

CHAPTER V

DESCRIPTION OF THE METHOD RESULTING FROM A PRELIMINARY TRYOUT

Role of the Exploratory Group

During the spring semester of 1942, following a semester of instruction within the established program for agricultural students of chemistry, the author launched an exploratory program which had as its purposes the evolution of the rationale described above, and the development of technics to implement it. Participation in the established program during the previous semester had provided some insight into the characteristics of the students with whom the course would have to deal; an attempt to adapt a course to their needs should provide a satisfactory means of selecting adequate procedures from those philosophically consistent with the rationale.

A section of Chemistry 144--the second semester of the freshman course--was set aside therefore for exploratory purposes. The members of the section had all taken the first semester of the established program, Chemistry 134, and had all been members of laboratory groups taught by the author; all were personally known to him before the beginning of the second semester. These students were not representative of all students of Chemistry 134, but were selected by the author because they were among the students with whom he was acquainted whom he judged to be sufficiently flexible and liberal in attitude to adjust themselves to a new learning situation, by no means fully perfected, with a minimum of conflict. They were not chosen because of academic or intellectual superiority. The section was also declared open to interested students of Chemistry 144 who had not been selected by the author, and included some such. Students of the exploratory section received full credit for Chemistry 144, but were exempted from the course requirements of the sections following the established method.

Since only one semester was available for the exploratory

program, and since technics for adapting the course to agricultural aspects of the situation were uppermost in importance, the several areas of student need were combined to provide the desired emphasis. All areas except 5, 8, and 9 (cf. chap. iii) were combined into a single group of "Problems Related to General Education Involving Chemical Principles." This included areas 1 and 2, which had not yet been eliminated from the experimental program. Area 5 was studied more intensely than all other areas combined, and areas 8 and 9 treated by the inclusion of materials dealing with the influence of technological advance on society, as well as through the organization of the course in such a way as to permit greater student participation and opportunity for clinical counseling than the established program.

No textbook was to be used, and no daily page-by-page assignments. Instead, the instructor and students would jointly compile a list of problems from which students would select those which interested them most for intensive study. Requirements were established as to the number and distribution of problems to be studied, but not as to subject. Each problem was to be made the subject of an annotated written report submitted by the student. Students working on the same problem were expected to form a panel discussion group, led by the instructor, to present their problem to the class.

A large list of selected references was compiled, and the books set apart as a special collection. The college librarian procured stack permits for the students of the special section; these were the first which the institution had ever issued undergraduate students. Certain sections of some of the books were set aside as required reading, and all books were combed by the instructor for relevant references which were specified in the annotated bibliographies with which the students were furnished.

Formal requirements as to time were minimized. Reports were due, not on a single date for each group of reports, but on a date selected by the student within a period of a fortnight. Students were required to report their readings on bibliographic cards which were collected each Friday, but were not required to turn in cards on every Friday. Furthermore, distinctions between laboratory, lecture, and discussion periods were abolished as far as possible. A lecture room was reserved throughout the laboratory periods, so that it would be available at any time discussion

arose concerning any point arising in the laboratory.

The exploratory situation was structured to this extent before launching, it being understood that procedures would be willingly modified in accord to the evolving needs of the students and in the light of experience in teaching the program. Two days prior to registration for the spring semester, the following postal card was sent to some fifty of the slightly more than one hundred students taught by the instructor during the previous semester--the fifty whom he judged most likely to co-operate successfully in the exploratory program:

Dear Mr. _____

Next semester, there will be offered for the first time an experimental section of Chemistry 144, designed to correlate more closely than has been customary with the problems in agriculture and daily living which confront agriculture students. This section will meet simultaneously with a regular section of Chemistry 144, of which it will be entirely independent. Full credit for Chemistry 144 will, of course, be received by students who enroll in this section.

Due to the novelty of the procedure, our work will doubtless be somewhat harder than that of the regular sections. I am, however, calling this section especially to the attention of those students who, I feel, would be most likely to profit from it, and who possess the qualities to make the greatest contribution to the success of the experiment, although the section is open to any student of 144.

Sincerely,

E _____ F _____

Response was immediate, and seemed enthusiastic. Many of those interested could not accommodate themselves to the schedule of the section. Twenty students enrolled for the section, 2 of whom were obliged to leave school early in the semester, and 2 of whom became very insecure in the exploratory program and returned to the established program toward the middle of the semester. The remaining 16, including 2 students who had not been included among the 50 who received special invitations to join, completed the program successfully.

Shortly after enrollment in the section, the students were asked to submit lists of problems which they regarded as important to the successful practice of agriculture. Many of the suggestions thus elicited were too general to be helpful in planning the course, others were concerned with problems stemming so directly from social defects as to be of little assistance in planning a course in chemistry. Others, however, were specifically embodied in the lists of problems available for study, other

problems in the lists having been selected by the author in conference with members of the staff of the School of Agriculture and through intensive search of the agricultural literature.

In discussion with the students it was agreed that three problems intensively studied, and one reading report on material related to the influence of science on society, would constitute a reasonable load for the semester. Two of the three problems were to be taken from area 5, the vocational area, and one from the combined areas mentioned above as related to general education. The first of the two problems from area 5 was to be chosen from those relating to dairy production, the second from those arising in connection with soils. Lists of these problems were submitted to the students with instructions to choose one as the basis of their report, or devise and submit another in the same area which would be of greater interest to them. These lists were the forerunners of the statement of student needs in area 5, cited in Chapter III, the earlier and more amorphous concepts held at the beginning of the exploratory program having been structured and refined in the light of the interests actually displayed by the students.

Early in the course it became apparent that the idea of teaching the class the role played by chemistry in each problem, by means of a discussion conducted by a panel of those students who had chosen the problem for intensive study, was working badly. Difficulties appeared to be due largely to differences in the capacity of students for verbal expression. Most of the students were markedly deficient in this capacity; listening to them was a trial, especially to those of their peers who excelled them. The group as a whole came to feel that the panel was not useful to them as a medium of instruction, and it was agreed that the instructor should discuss the problems in informal lectures with such comment by the students as they wished to contribute.

Since many persons with whom the course was discussed had difficulty in understanding how a course organized around student needs could still be quite definitely a course in chemistry, it may be of value at this point to summarize the discussion of some of the problems to show what facts and principles of chemistry were discussed by the exploratory group in connection with several of their problem areas. Chemical topics discussed in connection with problems related to dairy, over a period of some five weeks,

included:

1. The chemistry of the colloidal state. Characteristics of colloidal mixtures, smokes, emulsions, gels, sols, etc. Surface chemistry. Stabilization, Brownian movement, and the kinetic theory of liquids. The macromolecule. Inapplicability of concept of molar concentration to colloidal mixtures. Osmotic pressure, the salt-lactose relationship in milk, as an example of osmotic effects.
2. Acids, bases, and salts, with emphasis on the influence of electrolytes on colloidal mixtures. The measurement of acidity. Normality and pH. Strong and weak electrolytes, the Bronsted conception. Butter action. The isoelectric point, hydrolysis, and the common ion effect. The sorption of ions; lyotropic series. The concept of valence.
3. The chemical structure of fats, proteins and carbohydrates. Metabolism of food components. Basic units of structure of foodstuffs: amino acids and glucose. The concepts of energy and entropy. Oxidation.
4. Deamination, decarboxylation, hydrolysis and oxidation as related to the decomposition of dairy products and the development of flavors and odors. The double bond in the structure of the molecules of carbon compounds. Vapor pressure. Solubility.

In connection with the single problem, "How can I control insect pests," the following topics were related:

1. The chemistry of the various compounds which are used in insecticides: arsenicals, alkaloids, pyrethrum, and others.
2. Theories of detergent action. Concepts of surface activity, and polar and non-polar groups. Representative types of detergent compounds: gardenols, igepons, sapamines, and the relation of their properties to chemical structure. The work of Irving Langmuir. Traube's rule.

It is clear that, while this content was selected because of its relation to the problems studied, it is almost classically chemical in nature, and is altogether different from the content of a course in agriculture as such.

The question of laboratory work for the exploratory group was a difficult one. The procedure most consistent with the rationale of the course would have been to have each student develop under guidance experimental procedures to test the hypotheses which arose in connection with his problem. As has been pointed out in Chapter III, this was felt to impose an impractical burden of preparation on the stockroom staff. Instead, experiments whose content could be related to agricultural problems were selected from the laboratory manual purchased by the students for the first semester's work and were supplemented by experiments of a more markedly agricultural bias devised by the author. Examples of the former were experiments entitled, "The Preparation

and Properties of Colloids"; "Ionization, Chemical Activity of Electrolytes"; and "Acids, Bases and Salts--Neutralization."

Among the latter were experiments on observation of the isoelectric point of casein, isolation of the components of milk, and the qualitative analysis of a soil sample. The question of the kind and function of the laboratory report was also somewhat vexing. In the established course students were required to write reports in several formal sections. These seemed to have very little meaning for the students, who often filled them with errors of the sort which can stem only from almost complete lack of comprehension. They were tedious and time-consuming to grade, and of no value for purposes of evaluation in the exploratory group, since the writing of such reports was not a behaviour which we regarded as one of our objectives. It was decided, therefore, to require no laboratory report of the students, but that all of the written reports on problems selected by the student must contain a section in which the purposes, results, and relations of laboratory work were to be considered. This suggested a maximum of integration of the various types of learning experiences, and a minimum of unnecessary and unrelated writing of reports.

Evaluation of attainment of objectives, except for behaviours in areas 8 and 9 (effective democratic participation, and maturity) was a relatively straightforward problem. Since all objectives were conceived in terms of behaviour, evaluation was merely a question of the design of instruments to measure the degree to which sought behaviours had been achieved. This is usually difficult, but it is a technical not a philosophical problem. In areas 8 and 9, the behaviours are extremely difficult to measure quantitatively, and are subject to an additional threat to validity in that, unlike indications of ability to use knowledge, behaviours indicating maturity, or attachment to a democratic way of life, are utterly meaningless if exhibited in order to earn a reward or avoid a punishment. No progress was made toward the objective appraisal of growth in areas 8 and 9, but evaluation instruments designed to measure achievement in area 5 and the combined areas, while technically rather poor, were direct attacks on the problem and were later improved to a quite satisfactory level.

Formulation of the Method

As the work of the exploratory group proceeded, definite information as to the effectiveness of various aspects of it became available, to be used in the formulation of the procedure of the experimental group to be launched the next year.

The exploratory group appeared to adapt itself well to the personal roles which the exploratory situation required of its members. This situation had little in common with that prevailing in conventional freshman chemistry courses, or other courses at the undergraduate level at Oklahoma A & M College. These courses are, ordinarily, quite formal, altogether centered on content, and directed entirely by the teacher. While teachers and students often become friends--the wide respect accorded friendliness as a personality trait in this culture assures this--most teachers in the school would pride themselves on their ability to maintain formal class situations with lines of authority tautly drawn. In work with freshmen especially, this attitude is common. The director of the freshman chemistry program at a meeting of his staff, for example, once devoted considerable time to enjoining his laboratory assistants from eating candy in the laboratory. This was said to "bring the instructor down to the student's level," thus jeopardizing the stability of the academic structure which depends on the instructor remaining well above, and somewhat to the right, of the students.

In the exploratory program, dignity was felt to inhere in mutual respect for personality rather than in artificial standards of dress or behaviour. The establishment of barriers between the instructor and students, with consequent repression of attitudes which would otherwise have been expressed, would have hindered both clinical counseling and the garnering of information by which the course methodology could be improved. Spontaneous behaviour was, of course, made much easier for the students by the circumstances under which they came into the program. They felt that they had somehow impressed the instructor as being superior people, and that the program had been devised to help them and others like them. Shortly, they came to feel, and to state that they felt, themselves treated more as adults than teachers had previously treated them. They then began to identify themselves, satisfyingly, as participants in a "seminar course"--a term introduced by one of the more sophisticated Eastern students--and as participants

in an experiment designed ultimately to improve chemistry teaching by research.

These positive attitudes were not based on much insight into the nature of educational research, and when difficulties which appeared to the students as possible threats to their academic record arose they were easily rendered insecure. This occurred with great intensity following the administration of the first examination. The students were not accustomed to examinations purposely designed with a high "ceiling" to provide a more meaningful distribution of grades. They conceived examinations to be, not measuring devices, but challenges, and felt that a student who worked as hard as he should on a course ought to be able to answer every question on a fair examination. The first examination of the exploratory group provoked a storm of protest. "Hell, do you want to fail the whole class?" muttered one student. "Jesus Christ, what do you expect us to do with this?" shrieked another, and several students offered a suggestion.

A frustrating situation is more stable if it is sufficiently permissive to permit such outbursts. Their occurrence would appear to indicate two things: that there was something technically wrong with the examination, and that most of the students had formed a relationship with this class in which their self-respect and integrity were flourishing vigorously. There was other evidence that the more democratic relationships sought in this classroom had been partially achieved. Time was formally allotted each week for the discussion of method and formulation of policy, and the students were not hesitant in voting down procedures which they regarded as undesirable. Thus, a suggestion made by the instructor that an outline of all written reports be submitted in advance, which he felt to be justified by the disorganization of some of the reports, was carefully considered by the group and rejected.

The student-teacher relationships sought in the exploratory program provided much greater opportunity for clinical counseling by the classroom teacher than the less permissive relationships which arise in the more formal program. The author attempted to take advantage of this opportunity in providing for students who appeared to be emotionally disturbed. His efforts were hampered by two factors which decreased his competence in this area: great difficulty in eliminating his own needs and conflicts

from the counselling situation, and lack of an established counselling technic. In 1942 the non-directive technic was scarcely known in the hinterland, and a counselor was considered unusually well qualified if he was well grounded in the theories of personality developed by the psychoanalytic school and its associates. The question of method was not usually raised except by the directive school whose rationale was clearly not adapted to a program in which maturity and self-acceptance were regarded as indices of adjustment. The counselor was therefore left to devise his own procedures which became superficially psychoanalytic, being based on diagnosis, implicit or explicit, with an attempt to interpret the student's conflicts to him and often to compel his acceptance of the interpretations by argument. Such procedures become indistinguishable from those of the directive counselor except as they are motivated by a desire to help the student grow rather than to adapt him to an established norm. They are inefficient, and often ineffective. As an example of what was actually done in the exploratory group, an anecdotal description of the relation of the instructor to a mildly disturbed student is given here. This is not a case study, but an excerpt from a description of personnel written by the author for the information of his adviser at the conclusion of the exploratory program. It is presented without extensive revision in order to prevent possible retroactive inaccuracy:

The Case of Irving

Undoubtedly the most dramatic example of the profound behavioral affects of superficial maladjustment was Irving T. Throughout the previous semester, Irving had been the most serious problem student with whom the writer had had to deal. His behaviour in classroom and laboratory was aggressive, insolent, and disruptive. He assumed that any teacher would be his enemy, and would be of inferior social origin besides, so that the only rational course of action was to be as deliberately discourteous, and cleverly so, as possible. On one occasion he began a laboratory experiment without permission, and began it in a dangerous manner. On being told to disassemble the apparatus, he had protested that the instructor had no right to demand this, as he would not be involved in any explosion which might occur. On being told that anything which might occur in the laboratory would

certainly affect the instructor, he replied, "Oh, don't worry about that Mr. Friedenberg. I'll see that you don't lose your job."

He had been summoned to the instructor's office for conferences, but insisted on viewing these as disciplinary in intent. He would insist that the attitudes being attributed to him existed only in the instructor's mind, and that he was therefore being treated unfairly. His attitude was contemptuous and insecure at the same time.

Irving drives a beautiful 1941 sedan. In the course of conversation, between insults, it was gradually revealed to the instructor that Irving is the son of wealthy parents from one of the local oil centers. His vocational objective he stated as, "to be an oil speculator and get rich quickly." He was educated at a private school in Pennsylvania--a military school for boys like himself who are usually deemed by their elders to need every kind of discipline but self-discipline.

As relations improved gradually, Irving came to the instructor one afternoon, requesting help with some chemistry. The instructor suggested that they dine together. During the dinner, and following it, at the instructor's apartment, a general conversation concerning hotels, travel experiences, and other matters which the two held in common was held. After about an hour or two of this, the conversation turned to Irving himself. The instructor attempted to explain the boy's characteristics to him in terms of his feelings of social insecurity in a rural situation like this one, and his tendency to use material possessions to offset this feeling, and traced back his rebellious attitude to the military school experiences. (The officer of this school whose duty was to administer punishments was called the Dean of Good Citizenship.) Irving would not validate the suggestions; he made it clear that he accepted them but was merely unwilling to commit himself.

He appeared to be surprised at his inclusion in the group, but has worked harder in it than anyone else. His reports have been the best handed in; they are too good--they are spectacular like all the other characteristics the boy shows. On his information sheet Irving answered the question concerning personal problems by saying, in part ". . . from our conversations, I think you understand my problems pretty well, if I have any. . . ."

His attitude of enmity has utterly vanished; his arrogance, not quite so. He has got into the not especially desirable habit of dropping into the instructor's office some twenty minutes before each lecture period just for conversation. Occasionally he will examine the papers on the desk. If reproached for doing so, he replies calmly, "O.K., Sir. Just checking up." After every examination, Irving leads in the quibbles about whether a certain question was or was not too hard, until one of the other students yells at him; he then replies that he is not "bitching," but that "you can't blame him for trying." His interest in the work is unflagging, but does not appear to be based on any motivation except that this is virtually the first academic situation in which he has not been placed, or felt himself to be placed, in a hostile position. His attitude in this course is now abundantly co-operative and fairly responsible; improvement has been steady. It would be delightful to say that correspondingly great improvement has been made in all his relationships, but such is not the case. Within the past fortnight of school, he has provoked the chief stockroom keeper into hitting him, and gone upstairs to the office and announced that he intended to sue the department for the incident, precipitating a heavy emotional reaction which he did nothing to abate by pretending to be his own lawyer and telephoning the hapless stockroom keeper in the middle of the night. He has never mentioned this to the experimenter, whom he now treats with utmost respect, still mingled with a trace of the old vulgarity but with none of the contempt.

If the technics used in the exploratory program for achieving democratic student-teacher and interstudent relationships appeared to work fairly satisfactorily, the situation with respect to the laboratory work was highly unsatisfactory. The basic difficulty was, of course, that the laboratory work was not derived directly from the student's problem. The laboratory work could, therefore, be integrated in the problem report only in a general way, except by students with an unusual capacity for organizing material. The relationship of the laboratory work to the problems being studied was often not clear to the students, who became quite perfunctory in their performance in laboratory. This became clear when an experiment calling for a special reagent which the stockroom had neglected to provide was scheduled, and not a single student asked for it. In work closely related

to their problem topics the students appeared highly interested in the laboratory experiences. In a complex experiment on hydroponics, especially prepared for the group, the students threaded their way through a procedure much more complex than those typically found in a first-year experiment without faltering. Similar attention was given a specially devised soil analysis and a highly complex and rather tedious determination of the isoelectric point of casein. On the other hand, when the students were performing one of the experiments from their published laboratory manual, even though these experiments were selected for their agricultural applications, and these applications were carefully discussed in the preceding period, morale was often very low, and sporadic outbursts of disruptive behaviour occurred. On one occasion the most immature member of the group inserted his funnel into the trouser pocket of the state president of one of the most important young peoples' farm organizations and poured a large quantity of water into it from a beaker. This is not behaviour which ". . . demonstrate[s] by co-operation and tolerance respect for the personalities of others," although the victim's low but passionate, "I'll beat the tail off anybody who tries that again" may indicate a disposition to ". . . organize his work with a minimum of assistance from others. . . ." and there is no reason to doubt that had the offense been repeated, this intelligent and muscular young farmer would have "complete[d] undertaken responsibilities reliably."

No particular difficulties arose in connection with the reading. The transition from the accustomed textbook did not seem to disturb the students. Each report which the student submitted had a bibliography; these were of satisfactory scope in most cases. The system of recording outside reading on reading cards was, however, largely a failure, since no requirement had been formulated for handing in these cards although a time had been set aside to receive them. Comparatively few cards were submitted. Since this difficulty is clearly related to the difficulties which arose in the laboratory, where no practical report was required, it is apparent that a basic misconception of the nature of freedom impaired the thinking of the author--a misconception which resembles that noted by Rogers¹ in the thinking of some psycho-

¹Rogers, op. cit.

therapists. He stated that the counseling situation is much more effective if a few limitations are observed by client and counselor, provided these arise from the nature of the situation rather than the personal needs of the counselor, since in the latter case they may be interpreted as rejection by the client. Thus, non-directive therapy with adults is usually limited as to time, while in play therapy with children explicit limitations of physical activity must usually be imposed also. Such limitations are found to structure the situation in such a way as to permit freer use of it, rather than to limit the freedom of the client. Similarly, the lack of mutually recognized and enforceable procedures in structuring the laboratory and reading experiences seem to have partially vitiated them.

The reading resources available also required further selection. The students had discovered new materials superior to some of those which had originally been listed; others were selected by staff members who were interested in the work. Expansion of the reading list to provide a richer selection of materials dealing with problems in the areas which had been combined in the exploratory course was also needed for the two-semester program to be launched during the ensuing year.

Further thought was clearly required in the design of examinations. While those designed for the exploratory group were objective, and were constructed to measure the course objectives, the items were clumsy, difficult to understand, and difficult to grade. The latter objection would be extremely serious when the experimental program was launched, since it was anticipated that several hundred papers would have to be graded on certain of the examinations. It was clearly desirable that items be designed for machine grading if possible, and essential, if the co-operation of a large group be maintained, that the examinations be so designed that taking them would no longer be so traumatic an experience.

Opportunities for student participation in planning of the program would have to be adapted to a large group meeting in several smaller sections. No longer could policy be planned with the total group; a form of representative participation would be needed. Final plans must also be structured in greater detail than those which had guided the actions of the exploratory group.

Certain other defects of the exploratory program pointed

less clearly to their remedies. It was evident that the students in the program had responded favorably to the relationship which accorded them more nearly the role of adults than any they had previously enjoyed; that they did participate in the planning of the course; that they did resist the introduction of activities and obligations of which they saw no need; that some of them accepted clinical counseling. It was clear that they came to understand that their own purposes were respected; the very fact that they occasionally chose openly to meet a social obligation rather than turn materials in by the time they had agreed is evidence of this. But there was no evidence that the students were achieving through the course behaviours commonly considered as evidence of high social and intellectual maturity, especially where such behaviour involved a verbal component. Requirements or due dates listed in mimeographed material would usually be overlooked or forgotten unless emphasized in class. Social groups, such as those which formed to perform laboratory experiments occasionally, involved themselves in horseplay. Reports were seldom analytical and balanced examinations of all chemical aspects of the problems considered. Genuine preference for creative activity rather than following directions, so long as these were formulated with some regard for the interests of the student and were courteously given, was rare.

Undoubtedly much of the difficulty arose from an overestimate of the verbal skills possessed by these students. But this cannot be a final answer, since all the students were intelligent, and possessed skills more difficult to develop. It seems more logical to infer, not that intellectual attainments of a high order, including confident group participation toward an intellectual object, was difficult for them because their verbal skills were inadequate, but that their verbal skills were in fact adequate because their culture did not reward intellectual attainment or the pursuit of intellectual objects. It seems more logical to infer, not that many of the students rejected the opportunity for mature self-direction because they were too young to achieve it, or too inexperienced, but that they did so because they were experienced and knew almost instinctively that mature self-direction in a young person is more likely to be regarded by those in the community capable of affecting his material progress as a threat than as a virtue. Much of the emotional disorganization charac-

teristic of contemporary American culture seems to stem from the fact that opportunities for mature self-direction have so largely been eliminated from the economy. It is now possible only to those who are sufficiently objective to regard a diseased environment as a kind of natural phenomenon, without becoming emotionally disturbed by the values which it implies, and this is not a common attitude in young persons.

It is still true that a student needs to become a mature human being, and to participate effectively in the democratic process. But he does not need these things in order to make friends, or in order to succeed materially--the two values to which his culture most fully sensitizes him. He needs them to abate the dependency, truculence, or wistful, tense, gentle shyness with which a boy may seek to protect himself against the injuries he receives in stumbling among the economic and psychological wreckage of this century; wounds which seldom lead to the bitter consummation of tragedy, but, instead, to callous blindness and petty compromise in terms of no valued objectives until life becomes as formless and stale as an attic--a lumber room of broken, lost goals and rejected and unassimilated experience.

If, then, it is reasonable to expect that only small progress be made in a single college course toward the attainment of objectives which are, in a sense, opposed to values which the community teaches youth, (though not to those which the community believes it holds) it is surely reasonable to continue to seek to provide experiences which will help students to understand how important these objectives are. One must guard, chiefly, against one sole danger--the risk of inveigling students into the semblance of mature, democratic behaviour by extrinsic motivation which destroys its significance.

During the summer following the close of the exploratory program, a meeting of those members of the chemistry department staff responsible for the program offered to agriculture students was called to formulate plans for the full-year experimental program to be launched the next semester. These plans called for the setting up of an experimental group and a control group, matched by pairing according to scores on an entrance battery administered to all students in the chemistry department. It was necessary at this meeting also to formulate the methodology for the experimental group, so far as this could be done in advance. In doing

this, the experience of the exploratory group was naturally the chief guiding factor. Since this experience has been described above, the methodology as formulated may be summarized briefly:

1. Areas 1 and 2 of the pattern of needs would be eliminated from consideration.
2. The author would proceed immediately to develop laboratory experiments specifically dealing with the problems which the students were expected to choose for intensive study. Experiments from regular published manuals would be eliminated, except for a few to be used at the beginning of the course to acquaint the students with the use of laboratory equipment and the metric system of measures. Thus, only students who chose to work on problems not included in the lists derived from the analysis of needs would face difficulties in the integration of their laboratory work, and these might be expected to be so few in number as to permit special assistance to be given them.
3. The basic organization of the course around problems derived from areas of need would be preserved. Each area of need would be broken into specific behaviours, as in Chapter IV and a list of suggested problems in each area presented to the students for their choice. Students would be required to work on one problem each in areas 3, 4, 6 and 7, and two in area 5.
4. Those problems which had been chosen by several students would become the basis for lecture discussion by the instructor. These discussions would be concerned, not with complete solutions to the problem, but with the relation of chemistry to it.
5. Examinations would be objective and designed for machine grading. They would, of course, be carefully constructed to measure the course objectives.
6. There would be no textbook used in the experimental sections. A carefully compiled list of books dealing with chemical aspects of problems in all areas of need and social relations of science would be compiled by the instructor and submitted to the department well in advance of the opening of the fall semester so that the books could be made available to the class at that time. New materials could be added as discovered.
7. Reading cards, reporting and evaluating materials read in connection with the course work, would be collected each fortnight. Students who had done no reading during the last two weeks would be required to hand in a card stating that this was the case, but would not be penalized and need not justify their inaction.
8. Laboratory reports, consisting of answers to a short series of questions on each experiment, would be required.
9. A common background of reading in certain of the books included in the bibliography would be required of all students as assistance in understanding the discussion of problems which had been chosen by other members of the group.
10. Each laboratory section of the experimental course would

elect a representative to meet with the instructor each week to determine or modify policy. This member would be expected to bring to the attention of the instructor any feelings of dissatisfaction which a member of his group chose to direct through him rather than to the instructor, although any student could still make his complaints personally if he chose.

11. Grades would be based chiefly on examination results and evaluation of the students' written reports, and would be distributed normally so far as practical. In particular, the academic records of students would not be blackened by an attempt to impose absolute standards of achievement on a group dealing with an unfamiliar method.

This methodology was followed substantially by the experimental program, which will be described in detail in the next chapter. Changes were made, usually at the behest of the elected student committee, but were of a relatively minor character. For the convenience of the reader, certain essential points of contrast between the experimental procedure as it came to be applied and traditional procedures are enumerated here:

1. The experimental procedure used a selected reference shelf; traditional chemistry courses usually use a textbook.
2. The experimental procedure provided specific references to books dealing with relevant topics, but left the choice of reading to be done to the student; traditional courses usually make daily assignments of reading for which the student will be held responsible.
3. The content of the experimental course was given organization by its relationship to a previously established pattern of student need; traditional courses usually organize their content according to logical internal relationships rather than application.
4. The experimental procedure provided a formal opportunity for periodic consideration of the effectiveness of the course by an elected student committee which thus influenced policy; in traditional programs policy is usually determined solely by the instructor and the administration.

CHAPTER VI

DESCRIPTION OF THE LEARNING EXPERIENCES

Materials of Instruction

The materials of instruction of the course in inorganic chemistry adapted to the needs of agriculture students at Oklahoma A & M College may be divided into three groups: (1) materials in mimeographed form; (2) materials selected from available published works; and (3) materials written by the students themselves in discharge of the course requirements. Samples of the first group are collected in Appendix A.

Materials of Group 1

Within group 1, laboratory experiments received early attention, since the exploratory group had clearly been deficient in effective laboratory procedures. Published laboratory manuals of agricultural chemistry were carefully examined, but their purposes seemed usually to be the converse of those of the experimental course. They contained chiefly experiments designed to teach empirical procedures for using chemicals in agricultural operations, whereas the experimental course required experiments to demonstrate the application of chemical principles to agricultural problems. For example, several published manuals describe procedures for the Babcock test of butter fat in milk, without theoretical explanation. The experimental course, however, had much greater need of a procedure demonstrating the effect of hydrogen or metallic ions on the stability of milk, since such information can be integrated into treatment of the behaviour of acids, bases and salts as they affect dairy products.

Within areas 3 and 4, with which the first semester of the course was concerned, there was even less relevant published laboratory material available. The sheet from which students selected problems for study in area 3 (entitled "Selection Sheet and Detailed References for Problem Topics in Area 1," since the students were not aware that two areas in the formal classifica-

tion of needs had been deleted from the course) is included in Appendix A. The problems on it correspond exactly to the nine specific needs listed for this area in Chapter IV, and it was for these that laboratory experiments were devised. Time would not have permitted the performance of experiments for each problem, so experiments were devised to illustrate the application of chemical principles to those problems whose dynamics were best suited to laboratory study.

The first problem from the selection sheet, "How can chemistry help me to choose suitable metalware for the plumbing system of my home?" was supported in the laboratory by experiments A, B, and C. The purpose of experiment A was to demonstrate the fundamental reaction of rusting and corrosion--the oxidation of metal atoms by hydronium ions. Both hot water and dilute hydrochloric acid, which evolve hydrogen visibly, but at different rates, on contact with certain metals, were reacted with magnesium metal so that the influence of heat and hydronium ion concentration on rate of corrosion could be observed. Experiment B was designed to illustrate the "electromotive series" of metals. This is a common enough purpose among laboratory experiments in manuals of inorganic chemistry, but in experiment B ions to be reduced by more active metals are present in the solution as a result of previous oxidation of ions of less active metals, whereas in most such experiments separate vessels are used for each oxidation-reduction. Thus, in experiment B, the copper metal which plates out on the iron nail is derived from copper shot added to the original silver nitrate solution. The serial character of the "electromotive series" is thereby rendered clearer. Experiment C consisted of the identification of the metal ion contained in a sample of unknown salt.

Experiments D, D₂, and D₃ were designed to support topic 3 from the selection sheet: "How can chemistry help me to choose suitable paints, varnishes, or lacquers to finish my home. . . .?" In D, seven representative commercially used pigments were synthesized, and their resistance to solution or discoloration by hydronium, hydroxyl, and sulfide ions tested. In D₂, a practical lacquer was mixed and used to coat several small objects. In D₃, the students tested the effect of boiling water, hot dilute hydrochloric acid solution, trisodium phosphate solution, and drops of concentrated sulfuric acid on strips of wood and metal coated with

different finishes, including several alleged to be acidproof whose purchase and use as desk-topping was then being considered by the laboratory staff.

Experiment E, which was somewhat eclectic, dealt with some of the questions involved in topic 6, "How can chemistry help me choose suitable structural material for my home?"; topic 7, "How can chemistry help me to choose effective and safe antiseptics. . . .and disinfectants?"; and topic 8, "How can chemistry help me to choose dentifrices, shaving soaps, and other aids to personal appearance?" In the first section of this experiment the chemistry of the hardening of cement was studied by dispersing the powder in aqueous and non-aqueous media and observing effects; in the second section, the action of certain protein coagulant and oxidizing germicides was observed; in the final portion, some of the constituents of a tooth powder--abrasive, soap, and flavoring agents--were identified.

Topics 5, "How can chemistry assist me. . . .to choose a fuel for heating and cooking purposes?" and 9, "How can chemistry help me to use my refrigerator most effectively?" were supported by experiment F. It had been found in discussing these topics that most of the students found it difficult to distinguish in their thinking between heat and temperature; experiment F was a fairly conventional calorimetric experiment intended to clarify this difference.

Experiment G was not related to any problem topic, but grows directly out of a problem situation arising in the course. The reports which the students had submitted on problems in area 3 were discouraging in their poor semantic quality. The students literally did not use language effectively enough to demonstrate knowledge or ignorance of their problem topic; they demonstrated only that they were unaware that a word is distinguishable from its referent, or that the purpose of language is to aid one person in re-creating from his own experiences those of another person. The help of the department of English was sought, promised, and never given. Experiment G was therefore used to clear up the difficulty as far as possible; it is really nothing but a series of chemical pitfalls. It consists of three exercises which appear similar to those used in previous experiments, but which lead in each case to an impasse. Students are directed to collect gases which are never evolved and test them; to filter off precipitates

which do not form; to observe colors which never appear. The laboratory report on this experiment consisted of exercises in semantics, especially the identification of referents and operational meanings.

Within area 4 ("The student needs to support intelligently necessary public services") a similar procedure is followed. A selection sheet was prepared for problems in this area and distributed to students. Topic 1 of this sheet, "How does chemistry help my community or farm purify its water?" was supported by experiment H in which water artificially contaminated with turbid, coloured, and odoriferous material, separately and combined, as well as naturally impure water, was purified. Topic 3, "How can chemistry help my community in the detection of crime?" was supported by experiment I, in which two practical methods for developing fingerprints, one for detecting alterations in documents, and one for identifying bloodstains, were studied, and an arsenic sample quite inaccurately labeled "Extract from the stomach of Mrs. Gordon Esterhazy" analyzed.

All but two of the remaining laboratory experiments of the course were related to the vocational area, 5, in this case devoted to agricultural problems. Four of these were derived from a published source and will not be described here; they will be briefly noted in a later section of the chapter. Area 5 was administered as areas 3 and 4 had been; problems in this area were chosen from two selection sheets. The first provided for alternative choices of problems of dairy farming or pest control; the second listed topics related to soils.

Experiments L and L₂ were general studies of the chemical behaviour of milk, scarcely more related to one problem topic listed on the dairy sheet than to another. In them, the colloidal properties of milk are observed, especially the permanence of the suspension, and the distinction between the suspended and dissolved constituents. Electrochemical factors in the stabilization of milk were demonstrated by study of the relation between the magnitude of charge of added cations and coagulation time and of the detection of the presence of the cation in the coagulum. Experiment N, similarly, was concerned in general with the ampholytic properties of the casein micelle in milk rather than with a specific dairy problem. Experiment O, however, was concerned

specifically with the problem of insect control and consists of a volumetric determination of the copper content of a sample of Bordeaux mixture. Experiment P was concerned, somewhat more eclectically, with the same problem; in it a large variety of insecticides, fungicides, and rodent poisons are qualitatively analyzed and their active ingredients identified--the experiment also includes a systematic qualitative analysis of a patent chick-tonic.

Experiment R, "An Abridged Qualitative Analysis of Soils," was related to all problems in the soils subsection of area 5. Experiment S, however, was designed to support problem 3 on the soils selection sheet, ". . . . What materials are useful as fertilizer constituents, and what are the specific functions of each. . . .?" In this experiment unknown samples of pure substances commonly used in commercial mixed fertilizers were identified. All the substances tested in the procedure were salts, and their identification therefore required the recognition of the anion present as well as the cation, a fact of some interest in demonstrating that a chemistry course which is organized around student needs may actually draw more deeply on technical chemistry than a conventionally organized course in inorganic chemistry, many of which omit qualitative analysis, or teach chiefly the method of identifying cations which is much better organized.

Experiment T, the last of those prepared especially for the course, was derived from problem (a) of area 6, ("The student needs to make effective use of his leisure time"). It was a study of the chemistry of photographic processes. Emulsions and fixing solutions were prepared and the process of development studied.

In addition to laboratory experiments, many sheets of syllabus material were written and given to the students. These sheets were varied in subject and purpose; they were prepared whenever essential content was not readily available in the library materials gathered for the course. Such materials might become necessary in a number of ways. Thus, immediately after experiments A, B, and C were performed, the elected committee voiced many complaints that the students did not understand what they were doing, or what chemistry lay behind their results. Sheets entitled "The Theory Involved in Our Laboratory Experiments," analyzing these experiments, were immediately prepared

and distributed. For a different purpose, detailed outlines of an application of chemistry to each of the problems in area 3 (the students' first area), except problems (b) and (d), on which no one chose to work, were prepared and distributed. These were intended to serve both as lecture notes and as an example of a way in which acceptable reports on each of the problems might be organized. In later areas, where the students were assumed to be more familiar with the methodology of the course, no such aids were provided. Such sheets as the following were prepared in order to make readily available a complete statement on certain rather difficult theoretical questions which had arisen during discussion:

1. The Measurement of Concentration of Solutions and the Application of such Measurement to Volumetric Analysis.
2. The Proton Transfer Concept of Acids and Gases.
3. Explanatory Sheet on pH and Acidity.
4. A Mathematical Discussion of the Common Ion Effect in Weak Electrolytes.
5. A Discussion of Hydrolysis.
6. How Molecules Are Held Together, and How They May Break Apart.

Still other materials were issued as reference materials. These included a Glossary Sheet listing important elements and their symbols, and ions and their formulae; a Summary of the Meaning of Symbols, Formulae, and Equations; and a descriptive list of the Composition and Properties of Certain Important Alloys.

Likewise to be classed as materials of instruction were short mimeographed objective laboratory tests which replaced the students' written laboratory report on experiments P, R, and S. These were introduced because the laboratory reports, never very satisfactory, were becoming more and more sterile and less and less meaningful. It was thought that such tests might emphasize the important points of the laboratory discussion more clearly than the written report had done. These tests were not designed to measure the final, stated objectives of the course, and therefore were not regarded as evaluation instruments. Their purpose was purely to aid in laboratory instruction.

Appraisal, in retrospect, of the materials described, leads to mixed conclusions. Administratively they worked rather well. That is, the chaotic conditions which arose in the laboratory of the exploratory group did not arise with the experimental group.

The experiments worked well; nearly every student was able to get the desired results without much difficulty. They were eminently safe; not a student even burned himself during the entire course. Instruction by means of the experiments was moderately successful; while no data were available as to the effectiveness of learning induced by the laboratory, the level of confusion and random behaviour appeared to be lower than with experiments found in conventional laboratory manuals and unrelated to student needs, although it is certain that the instructor did not succeed in conveying to the students all the significance which he believed the experiments to possess. The theoretical materials given to the students also appeared satisfactory, and there is evidence that they served a function at least in so far as complaint as to the obscurity of experiments A, B, and C abated following the issuance of the sheets purporting to explain them. In general, however, it seems more realistic to regard these theoretical materials suspiciously, and to ask whether many of the students attempted to use them. One wonders, indeed, if they did not have their origin in an emotional, or even political, need of the instructor to demonstrate that a course organized around student need could contain sound chemistry. If such content is appropriate to the course, which it can be only if it helps students to formulate better answers to problems than they could without it, the usefulness of the materials may probably be assumed.

There are, however, some rather serious objections to be raised to these materials--particularly the laboratory experiments. While a great improvement over the arrangements made for the exploratory group, it is clear that these experiments are neither perfectly nor consistently related to the problems which the students have chosen. It is perfectly true that the principles illustrated by experiments A, B, and C are involved in a sensible choice of metal for plumbing. Such a choice can, however, usually be made on the basis of empirical knowledge; at any rate, the question of how much theoretical chemistry or thermodynamics one is justified in learning in order to make such a choice deserves attention and has received very little.

A, B, and C stand in quite a different relation to the problem of the choice of metalware than experiment D does to paints and varnishes, or E to structural materials and cosmetics. The former are related by fundamental theory, although the mate-

rial used differs markedly in form from the way it occurs in the household; in D and E actual paints, cement, and tooth powders are used, but the theoretical relations involved in the experiment are rather trivial. Particularly in those experiments involving analysis, it is difficult to see how the chemistry involved is related to the use which the student expects to make of the substances analyzed, even if they are real commercial substances. Only in such experiments as those dealing with the purification of water, or the detection of crime, where both the materials and the chemical processes involved in the experiment are reproduced, is the relation of laboratory experiment to problem satisfactory. Particularly in the experiments designed for use with the dairy problems, it becomes impossible to assign each experiment to any particular problem. The flat truth is that these experiments are as highly academic in context as those found in traditional chemistry courses. While they will contribute more to the solution of dairy problems than experiments which do not deal with dairy products, they still cannot be regarded as completely consistent with the course rationale. The problem of integrating the laboratory work fully into the course experience, which was so serious in the exploratory program, has not been fully solved.

Instructional Materials of Group 2

Although some published laboratory experiments were used, most published instructional materials employed by the course served as reading references. The most prominent among these books will be described in detail here in order to show what kinds of materials were deemed useful. Complete references to the books is given in the bibliography of the dissertation.

1. Ahrens, Bush, and Easley, Living Chemistry.--This is a high school text-book, published by three members of the science staff of the Denver city schools. It is organized in a manner closely similar to the experimental course, although it does not emphasize agriculture more than other vocations. It is reasonably accurate and especially pleasing in format, being profusely illustrated with pictures which contribute markedly to understanding of the text rather than with woodcuts of alchemists and distinguished members of the Royal Society. It is too superficial to be used unaccompanied as a college text, but provides an invaluable picture of the relation of chemistry to the problems of young people.

Living Chemistry was much more popular with the students than any other reference used in the course, and was especially helpful with problems in area 3. The references at the end of each chapter are not suitable for use in a college course.

2. Holmes, Harry N., Out of the Test Tube.--This book contains several unusually simple, lucid chapters on such theoretical topics as atomic and molecular structure, ionization, and the periodic table, followed by chapters dealing with the contribution of chemistry to various aspects of living. These last are very brief and superficial, and contain little information of value. The style of the book is occasionally marred by those touches of forced whimsy which are presumed to adapt scientific works to popular audiences.

3. Rice, Oscar K., Electronic Structure and Chemical Binding.--This is one of the best works on atomic structure and its influence on chemical properties. While too profound for general use by all members of a first-year course, it is very lucid, considering the abstruse nature of the material. It contains very little mathematics. This book may, however, have been superseded for purposes of general education by some of the new treatments inspired by public interest in the atomic bomb.

4. Riegel, Emil R., Industrial Chemistry.--This book is designed as a textbook in chemical technology or elementary chemical engineering. Books in this field are often more adaptable to the purposes of a course organized to meet student need than an elementary text, since textbooks in chemical technology are usually organized around specific substances rather than theoretical principles. This book contains chapters on glass, paints and varnishes, war gases, cement, and nearly every other important product of chemical industry, and deals not only with manufacture of materials but with uses, properties and costs as well. References to primary sources are given at the end of each chapter.

5. Rhodes, H. T. F., Forensic Chemistry.--A scholarly and complete account of the use of chemistry in the detection of crimes against the body and against property. This book is of unusual interest to students.

6. Buswell, Arthur M., The Chemistry of Water and Sewage Chemistry.--All the ACS monographs are scholarly, exhaustively annotated, and written in a standard, coherent prose. Where they

deal with an applied field, they may be trusted to have a thorough and profound emphasis on chemistry. A new edition of Buswell was in process of preparation in 1942 and should now have been published; if it has, it is doubtless the best in its field.

7. Associates of Lore Rogers, Fundamentals of Dairy Science.--This is unquestionably the most authoritative and complete work published on the relation of chemistry to dairy problems. Certain sections of this work were made required reading for all students, including all of part 1 (The Constituents of Milk), part 2 (The Physical Chemistry of Milk and Milk Products), and Chapter XII, part 3 (Influence of Physical and Chemical Factors on Bacterial Growth). Much of Rogers is so profound as to be difficult to understand, but is as clearly written as the content permits. From one- to three hundred references to periodical literature are given at the end of each chapter.

8. Martin, Hubert, Scientific Principles of Plant Protection.--This book is as complete, in its own field, as Fundamentals of Dairy Science is in its. Martin's procedure is to begin with fundamental theory of insecticide and fungicide action, including that of substances used as spreaders, stabilizers, and wetting agents, and to continue with a discussion of individual insecticides, fungicides, fumigants, and weed killers according to a classification based on chemical composition. The book concludes with a chapter on frontier theories of the relationship between chemistry and toxicology in insect control. It is exhaustively annotated.

9. United States Department of Agriculture, Soils and Men.--The Department of Agriculture yearbooks have, for about the past ten years, been exhaustive treatments of a single broad area of agriculture, rather than reviews of agricultural researches of the previous year. They are superb documents--models of clarity and of completeness in content and annotation. Chapters in these yearbooks are not numbered; among the headings of those listed as required reading were: Loss of Soil Organic Matter and Its Restoration; Soil Nitrogen; Phosphorous Deficiency and Soil Fertility; Soil Potassium in Relation to Soil Fertility; Crop Rotation; The Use of Cover and Green Manure Crops; Farm Manure; The Nature and Use of Organic Amendments; Determining the Fertilizer Requirements of Soils; Requirements of Soil Fertilizer Materials; Mixed Fertilizers; Methods of Applying Fertilizers; Soil Acidity and

Liming; The Soil Requirements of Economic Plants; Some Relationship of Soil to Plant and Animal Nutrition--the major elements; Neglected Soil Constituents That Affect Plant and Animal Development; Selenium in Soils; Plants as Soil Indicators; Soil and Society; The Physical Nature of Soil; Water Relations of Soil; General Chemistry of the Soil; Soil Organic Matter and Soil Humus.

10. Prentis, Augustin M., Chemicals in War.--This is an excellent, scholarly work on toxic gases, screening agents, and incendiaries. It does not include explosives, and must therefore be supplemented by other materials. Riegel,¹ however, contains a satisfactory chapter on molecular explosives.

11. Bernal, John D., The Social Function of Science.--This, in the writer's judgment, is the most scholarly, urbane, and analytical book yet published concerning the vital relationship between science and contemporary capitalist society. Bernal examines with unimpeachable logic the effect of such phenomena as patent suppression and the necessity for profitable operation, the contribution which science makes to our culture, and examines the possible contribution in a society so organized as to minimize these factors. He surveys the status of science in all parts of the world at the time immediately preceeding the outbreak of the second World War and summarizes objectively the psychological and sociological conditions surrounding scientific employment. He does not, unfortunately, deal with the converse effect--the influence of scientific advance on the validity of economic folklore. This book was required reading for all students, who were obliged to make a written report on it.

Published materials, where appropriate, were also used in the laboratory, and consisted of experiments from Burrows, Arthur and Smith, Semimicro Laboratory Exercises in General Chemistry. Before beginning the series of experiments prepared for the class, five experiments from this source entitled: Some Common Measuring Units Used in Science; Density and Specific Gravity of Liquids and Solids; Bunsen Burners; The Working of Glass; and Some Simple Laboratory Techniques, were performed to acquaint the students with the equipment and nomenclature of the laboratory. Later, experiments from this source were used to support study of particular areas or problems. Thus, the dairy problems were sup-

¹Reference 4, p. 71.

ported by two experiments entitled: The Preparation and Properties of Colloids, and A Colorimetric Method of Determining pH; Buffer Action, while problem 4 on the soils selection sheet, "What elements are essential to plant growth. . . ." was supported by an experiment called: The Preparation and Properties of Ammonia; Ammonium Compounds, and problem (c) of area 7, dealing with defense against explosives was supported by the experiment Relationship of the Volume of Gases to Their Temperature and Pressure.

In addition to published materials from books, an effort was made to teach students how to use the bibliographies of such works to locate primary sources in periodicals. Students were urged to include such materials in their reading cards, and were required to cite two primary references for their report on the soils problem.

Materials of Group 3

It had been intended throughout the course that the student reports should deal with problems rather than subjects. Students were expected to select problems of interest to themselves, and to have specific ideas as to why such problems were important before attempting to gather scientific information about them. They could then use suggested reference materials to find information relevant to the solution of the problem. The completed paper would consist of the best possible answer the student could give to the question he had raised for himself, arranged to emphasize what he felt to be important, and annotated so as to document his statements and provide guidance to others who might wish to study similar problems later.

Few of the students were sufficiently independent intellectually to follow such a procedure successfully. They were not accustomed to the use of published sources of information for specific purposes. Books do not play an important part in the life of the Oklahoma farmer, and where used, they are used uncritically, and, for the most part, unselectively. To most of these agriculture students, books have a symbolic rather than a practical value. Such a boy derives some sense of security from believing that the exact information required for the solution of almost any problem is contained in some book on the subject, and he assumes that bibliographic resources will be used by the proper

authorities to provide simple solutions to his serious problems, unless they are prevented by chance, corruption, or incompetence. He does not realize that books can only summarize the experience of trained observers with situations similar to, but not identical with, his own, and he regards the eclectic use of these summaries for the construction of solutions to new problems as in some way impertinent to their authors.

In its most extreme form this viewpoint leads to outright copying from published sources. Many of the papers written on problems in area 3 were copied directly from Living Chemistry. There was apparently no subterfuge intended in this procedure. The students were not embarrassed when detected, but could not understand at first why their papers were considered unsatisfactory. They defended them by insisting that these authors were much better qualified authorities on chemical subjects than they were. A more common, and much less easily altered consequence of this viewpoint was the tendency of students to forget that they were working on a problem and start writing on a subject. That is, they would omit to consider what aspects of their subject were of importance to them, and would set out to get as much information as possible on it, paraphrasing the statements of various authors and presenting the result, without integration, as an original contribution.

More subtly flawed reports were written by students sufficiently sophisticated to conform to the appearance of problem solving but unable to advance their solutions beyond a verbalization which had little operational meaning. It is perhaps a creditable accomplishment to get even this far in one's first opportunity for full-scale intellectual responsibility, and the results of such verballity were often sufficiently impressive. The defect would be revealed by failure to recognize the existence of well-known local or contemporary conditions--the suggested use, for example, of materials never available in Oklahoma, or made unavailable by the war. Finally, there were a few reports--the achievement of very few students in the course--in which the author appeared to have chosen a problem which was real to him, to have a clear idea of its practical importance, to have searched the literature for information specifically related to it, and to have achieved insight into the way in which chemistry could be used in its solution.

Log of Learning Activities and Content

The variety of kinds of learning experiences afforded the experimental group was probably not greater than is available to students in a conventionally organized chemistry course. As indicated in the preceding discussion of methodology, only quite familiar teaching technics--readings, lecture-discussions, written reports, and laboratory experiments--were used. Even field trips were omitted from the program, due to wartime limitations on transportation and access to chemical installations. While demonstrations were frequently used to illustrate the lecture discussions, the experimental program made very little use of other visual aids.

This section of the report will be, therefore, largely a chronological summary of course content. Unless otherwise noted, it will be assumed that this content was taught by the method described in Chapter V under the subheading "Formulation of the Method." Since one of the chief purposes of adapting a course to student need is to permit each student to choose a pattern of learning experiences appropriate to himself, no two students of the course had identical curricula. All had certain readings, certain laboratory experiments, and the lecture-discussions in common, however, and it is with this common core of content that we are currently concerned.

As indicated in Chapter V, those problems which were chosen by several students were analyzed in the lecture-discussions. Problems were not always discussed in the order in which they were listed on the selection sheet, since in some cases relationships between the problems made another order more useful to the students. Discussions will be summarized here in the order in which they occurred.

1. Area 3 (student's area 1). The Student Needs to Be an Effective Consumer of Goods.

Considerable interest was shown in all problems listed on the selection sheet for this area, except, "How can chemistry help me to choose and care for glassware and window glass in my home?" and "How can chemistry assist me in choosing china, earthenware, and enameled articles for use on my table and in my kitchen?" which no student chose. The remaining problems were discussed as indicated:

- a. How can chemistry help me to choose suitable metalware for the plumbing system of my home, kitchen utensils, and other exposed metallic devices?

(1) Atomic structure.

The relation of atomic structure to chemical activity. The electromotive series. The periodic chart. Explanation of the chart by elementary quantum theory. Prediction of metallic behaviour from atomic structure and position on chart.

(2) Properties necessary to useful metals.

Metals, to be suitable for household uses must not (a) be readily attacked by moisture, and (b) contaminate water with toxic ions if slightly attacked. Hydrogen and its metallic behaviour. Oxidation reduction reactions between hydronium ions in water and metal atoms.

(3) Characteristics of the common metals.

Cost factors in choice. Effect of characteristics of the water supply on choice of metals for plumbing--copper versus iron.

(4) Properties and uses of the common alloys.

National and world distribution of the commercial ores; their effect on world economy and the war effort.

b. How can chemistry help me to choose a suitable structural material for my home?

(1) Essential properties in a structural material.

Cheapness, strength, ease of shaping, chemical inertia. Cheapness as a function of abundance and availability. Strength as a function of intermolecular binding. Intermolecular versus interatomic binding. The concept of the macromolecule. Crystal structure. Chemical inertia, and its relation to corrosion resistance, combustion, and attack by microorganisms.

(2) Manufacture, composition, and properties of leading structural materials.

Brick, concrete, and glass as silicates; chemical characteristics of the silicates. Wood, its structure and properties. Photosynthesis in plants. The cellulose molecule and the glucose unit.

c. How can chemistry help me to choose suitable paints, varnishes, and lacquers to finish my home. . . .?

(1) Characteristics of a satisfactorily finished surface.

Durability, beauty, ease of cleaning. The need for establishment of tough, continuous film, having all the properties of a structural material except tensile strength.

(2) Properties and composition of the common surface finishes.

Calcimines, whitewash, paints, varnishes, enamels, lacquers. Role of constituent resins, drying oils, pigments, solvents. Oxidation in the chemistry of drying.

(3) Composition, colour, and covering power of the common pigments.

The deterioration of painted surfaces. Causes, results, and prevention of photochemical decomposition, chalking, and deplasticizing.

The next two problems were combined for discussion, since both dealt with materials which are commonly sold by identical merchandising methods, from drug stores, on the basis of national campaigns of advertising. They present, therefore, similar problems to the consumer.

- d. How can chemistry help me to choose effective and safe antiseptics, germicides, and disinfectants for various purposes?
- e. How can chemistry help me to choose dentifrices, shaving soaps, and other aids to an attractive personal appearance?

(1) The chemistry of detergent action.

Polar and non-polar characteristics of portions of large molecules; preferential attraction for water and for "dirt" or grease. The effect of detergents on surface tension. The physical chemistry of emulsification.

(2) Composition and properties of classes of detergents.

Soaps, gardenols, igepons. Special purpose detergents--shaving soaps. Purpose of glycerine and stearic acid in shaving soap.

(3) Dentifrices, deodorants, and depilatories.

Composition and properties. What these can and cannot do. Which are safe, and which dangerous. The scientific status of hair tonics. Limitations of topical application in therapy of skin diseases.

(4) Germicidal substances as direct, protoplasmal poisons.

Range of toxicity of germicides. Substances which destroy any protoplasm--iodine, phenol. Selective agents which kill only certain organisms--sulfa drugs, arsphanamine, quinine. Maximum specificity attained by antigens actually produced in body. General internal antiseptics impossible because of toxicity of all known agents. Chemical structure and properties of the better known antiseptics and germicides.

The last two problems in area 3 were combined because of the similarity in their theoretical background:

- f. How can chemistry assist me to choose. . . wisely. . . a fuel for heating the home?
- g. How can chemistry help me to use my refrigerator effectively?

(1) Thermodynamics of refrigeration.

Work needed to transfer heat from cooler to warmer material. Thermodynamic relationships in compressor type refrigerator.

(2) Desirable properties in refrigerants.

High critical temperature and heat of vaporization; low boiling point and toxicity. Chemical composition and properties of the common refrigerants.

(3) The house as a part of a thermodynamic system, including the body as a source of energy. Methods of heat transfer from the body: radiation and convection. Temperature relations within the body. Effect of temperature on reaction rates. Constant temperature needed for maintenance of metabolic equilibria. Methods by which body compensates for temperature changes, and their limitations.

(4) Sources of energy in fuels.

The sun as the source of all useful energy. Photosynthesis and the capture of solar energy. Oxidation an exothermic process. Combustion as oxidation. Chemical characteristics of common fuels--wood, coal, natural and synthetic gases.

(5) Methods of heat transfer in houses.

Direct combustion and radiation in stoves or fireplaces; through heat exchange media by central heating; by radiation from heated wall surfaces.

3. Area 4. The Student Needs to Support Intelligently Necessary Public Services.

Problems in Area 4 were discussed in the following order:

a. How does chemistry help my community or farm purify its water?

(1) Objectives of water purification.

Removal of pathogenic organisms, color, odor, and turbidity. Unit processes in the typical purification plant--slow and rapid sand filtration, treatment with aluminum sulfate, activated charcoal treatment, chlorination.

(2) Water softening.

Permutit and other home water softeners. Chemical nature of hard water. Chemical changes in water softening.

b. How can chemistry help my community or farm dispose of sewage?

(1) Sewage as a possible economic resource.

Conversion of sewage into fertilizer--the Milorganite process. Fermentation of sewage to produce fuel gas--the activated sludge process.

(2) Techniques of rural sewage disposal.

The construction of the septic tank. Chemical changes in the operation of the septic tank.

c. How can chemistry help my community in the detection of crime?

(1) The identification of the person.

Methods of fingerprint identification--iodine method, silver nitrate method. The scientific examination of bloodstains. Methods of identification of stains as blood, human blood, or blood of a particular type. Benzidine and agglutination tests. The scientific impossibility of determining the racial origin of a blood sample.

- (2) The establishment of the corpus delicti.

The examination of suspected alterations in documents. Chemical observation of the extent of oxidation of ferrous ion in ink samples. Toxicological investigation of the remains of suspected victims of poisoning: the chemistry of tests for arsenic, carbon monoxide, or cyanide poisoning.

- d. How can chemistry help our country replace scarce essential materials needed in the war effort?

For the discussion of this problem a guest speaker, an organic chemist of national reputation, was invited to assist the instructor in presenting the material. Among the content considered was:

- (1) The situation with respect to rubber.

Distribution of supplies of natural rubber. The synthetic rubber program. The chemical composition, properties and uses of various kinds of synthetic rubber.

- (2) The situation with respect to metals.

Distribution of the essential metal ores.

- (3) The development of substitute materials for civilian use.

The newer plastics.

- e. How does chemistry help my community prevent and extinguish fires?

- (1) The chemistry of combustion.

Chemical factors necessary to produce flame--exothermic reaction, energy sufficient to initiate reaction in adjacent materials, gaseous products.

- (2) Chemical changes in fire extinction.

Reduction of temperature of combustible material below kindling temperature; exclusion of one of the reagents, air, from the site of the reaction.

- (3) Types of fire extinguishers and their properties.

The soda-acid and carbon tetrachloride extinguishers stressed.

- f. How does chemistry help our government enforce pure food and drug legislation?

- (1) Precise measurements in chemistry.

The stoichiometric reaction. Constancy of composition in molecules of pure substances. Molecular and equivalent weights.

(2) The measurement of concentration.

Molar and normal solutions. The calculation of percentage composition from molarity measurements.

The remaining two problems in this area, "How does chemistry help our government maintain standards of weight, volume, and temperature?" and "How does chemistry help our government to construct highways?" were chosen by only one student each; they were therefore omitted from discussion. With the discussion of problem f, the work of the first semester ended.

3. Area 5. The Student Needs to Earn a Living by a Worthwhile Contribution to the Community.

During the second semester, area 5 supplied the greater number of problems considered. Two intensive reports dealing with problems in this area were required of students; one from a subarea including problems of dairy and pest control, the other from a subarea including soils problems. In the first subarea, the following problems were included:

- a. How may undesirable flavors and odors in milk be prevented?
- b. What chemical factors affect the production of butter-milk and cheeses?
- c. What metals would you choose for the construction of dairy equipment?
- d. What are the chief constituents of milk, and how is it stabilized?
- e. What chemical factors are involved in preventing undesirable bacterial or zymotic changes in milk, and fostering desirable ones?
- f. What physico-chemical factors must be considered in the freezing of dairy products?
- g. How can chemistry help me control predatory insects?
- h. How can chemistry help me control harmful fungi?
- i. How can the effectiveness of insecticides be augmented by the use of non-toxic ingredients?

Of these topics, only a, d, and g attracted much interest. No reports were written on c, e, h, or i, and only one on topic b. While problems in area 5 were not as sharply distinguishable from each other as those in other areas, the same procedure was followed in studying them. The problems were made the subject of consecutive classroom discussions, which were dominated largely by the instructor; these discussions were chiefly explanatory and analytical lectures, interrupted by students who wished to have obscure points clarified, to have supplementary

information given, or to contribute additional material from their own reading or experience. At the beginning of the series of lectures on problems of area 5, a selection sheet and bibliography for problems of the dairy subarea were distributed. These bulletins listed problems for study, from among which a selection might be made; designated several reference works as suitable sources of information, and stipulated such administrative minutiae as due-dates and means of indicating choices.

Student activities, so far as planned and provided for, consisted only of readings, the preparation of a written report upon the topic chosen, and the performance of laboratory experiments described earlier in this chapter. If the student were a member of the elected student committee, he also bore considerable administrative responsibility for the conduct of the course; if not, he had no direct contact with the administrative function. It can be seen, thus, that although it was in area 5 that the variation of the course content from that of the traditional course became most intense, no corresponding increase in the scope and richness of student activity occurred. The kinds of learning experience provided remained virtually identical with those of a highly conservative chemistry course. The content of discussions of problems taken from the dairy and pest control subarea is outlined as follows:

a. How may undesirable flavors and odors in milk be prevented?

(1) Internal sources of undesirable flavors and odors.

Rancidity--fat hydrolysis and free fatty acid.
Tallowiness--oxidation at the double bond of the fatty acid molecule. Fishiness--trimethylamine formed by decomposition of lecithin associated with butter fat.

(2) External sources of undesirable flavors and odors.

Feeds, barnyard odors as sources of contamination. The role of solubility in affecting ease of contamination. Substances most soluble in other substances of similar composition. Milk, as a mixture of fatty and aqueous phases, particularly susceptible to such contamination.

(3) Catalysis as a factor in causing undesirable flavors.

Copper as a catalyst in the oxidation of unsaturated fatty acid esters. Copper dairy equipment a cause of tallowiness.

(4) Inverse relationship of lactose-salt content of milk.

Osmotic constancy a factor in determining milk flavor

- b. What are the chief constituents of milk, and how is it stabilized?

(1) Composition of milk.

Dissolved and colloiddally dispersed constituents. Range of particle size. Variations in composition of milk of various animals.

(2) The basis of stability in milk.

Relationship between lyophillic and lyophobic constituents. Solvation and electrostatic repulsion as stabilizing factors. The role of stabilizing agents and the Gibbs rule which describes their formation. Stability and cation concentration. The lyotropic series. The hydrogen ion in casein coagulation. Measurement of hydrogen ion concentration on the pH scale.

- c. What physico-chemical factors must be considered in the freezing of dairy products?

The extrusion of dissolved substances in the freezing of solutions--analogy to distillation. Crystallization of lactose in the freezing process a cause of sandy texture in ice cream. The reduction of crystal size by incorporation of stabilizing agents in the freezing mix.

- d. How can chemistry help me control predatory insects?

(1) Composition and properties of various insecticides.

Insecticides and fungicides of the copper and sulfur groups. Arsenical insecticides.

(2) Uses of the various insecticides.

Contact and stomach poisons. The role of detergents in increasing the effectiveness of insecticide action.

The selection sheet for the second subarea of area 5 included the following problems, here listed in somewhat abbreviated form:

- a. What elements are essential to plant growth; how do they occur; how are they lost; and how are they replenished?
- b. How may depleted soil constituents be replaced?
- c. How may farm products of little commercial value be used as soil amendments?
- d. How can chemistry be used to maintain desirable soil textures?
- e. What are the relations between cropping, soil composition, and animal or human nutrition?

Topics "a" and "b" were chosen by only two students each; the remainder were of considerable interest. These three problems are so closely interrelated, however, that separate, discrete discussion of each one did not seem desirable--all have similar chem-

ical backgrounds, and there is some overlapping of detail. Class discussion in this area was therefore not related to each problem consecutively, but implications for each problem were indicated as they occurred. The same procedure will be followed in outlining the discussion in this report:

- a. What elements are essential to plant growth; how do they occur, how are they lost, and how replenished?
- b. How may depleted soil constituents be replaced?
- c. How may farm products of little commercial value be used as soil amendments?

- (1) Origin of soil in decomposition of rocks forming earth's crust.

Most abundant soil elements those of rocks rather than those needed in plant nutrition. About 10 per cent of soil constituents valuable to plants.

- (2) Ionic equilibria in soils.

The soil as a negatively charged micelle; most plant nutrients present as cations in soil solution. Only dissolved soil components available for plant nutrition.

- (3) Classification of substances needed for plant growth.

Elements required in abundance: potassium, nitrogen, phosphorous. Elements required in small amounts: calcium, magnesium, sulfur. Elements required in traces: iron, copper, manganese, boron, and others.

- (4) Effect of agricultural intensification on plant nutrition.

Inadequacy of elemental "cycles," based on decay of dead plants, to supply modern agricultural needs. Necessity for development of modern fertilizer industry.

- (5) Effect of continued use of synthetic fertilizers on soils.

Purity of modern fertilizers. Trace elements no longer replenished. Effects due to greater solubility of synthetic fertilizer constituents. Reactions affecting availability of fertilizer constituents in plant nutrition. Phosphorous availability and calcium content.

- (6) Effect of soil amendments on texture.

The role of organic matter in soil. Manure and peat moss as amendments. Effect of plowing on rate of oxidation of soil organic matter. Legumes as sources of carbon rather than nitrogen.

4. Area 6. The Student Needs to Make Effective Use of His Leisure Time.
5. Area 7. The Student Needs to Defend Himself Against Hostile Forces in the Environment.

Late in the spring of 1943, it was announced by the administration of Oklahoma A & M College that the semester would be shortened by several weeks in an effort to permit those students who were members of enlisted reserve corps to finish the academic year. This deprived the course of most of the time which would have been available for the study of problems in area 6, and area 7. These areas were therefore combined, and only one report required of students on problems in both of them. No selection sheet was mimeographed for these areas. Instead, the areas were discussed with the class, and the following problems recommended as possible choices:

- a. How can chemistry contribute to my enjoyment of photography as a hobby?
- b. How can chemistry assist the military use of:
 - (1) Explosives.
 - (2) Poison gases.
 - (3) Indendiaries.

The reasons for this rather odd choice of problems are discussed in Chapter IV.

The content discussed may be outlined as follows:

- a. How can chemistry contribute to my enjoyment of photography as a hobby?

- (1) Chemistry is involved in the various steps in photography.

Exposure: photochemical reduction of silver bromide. Development: reduction of silver bromide catalyzed by presence of photochemically deposited silver. Composition of developing mixture. Fixation: complex formation in rendering soluble unreduced silver bromide.

- (2) Precautions taken in the control of the chemical reactions of the photographic process.

Chemical and photographic consequences of improper exposure time, or improper concentration or temperature of reagents.

- b. How does chemistry assist the military use of explosives?

- (1) Thermodynamics of explosives.

An explosive is a compound in the synthesis of which much energy is consumed, and in the decomposition of which much energy is released. Factors determining desirable rate of decomposition reaction.

- (2) Physics of explosives.

Products of reaction must be gases, for expansion, and to avoid fouling of pieces.

(3) Composition of explosives.

All commercial molecular explosives nitrogen compounds. Detailed discussion of structure and properties of glyceryl trinitrate, trinitrotoluene, amatol, tetryl, and the fulminates.

c. How does chemistry assist the military use of poison gases?

(1) Classification of gases.

Vesicants, lung irritants, and lachrymators. Most agents combine properties of two or all these classes, but are primarily active as one or the other. Very few are gases at ordinary temperatures.

(2) Composition and characteristics of individual agents.

Mustard gas, lewisite, phosgene, chlorpicrin, bromacetone, and others.

(3) Protection against poison gases.

The structure and function of the gas mask. Action of activated charcoal, sodium permanganate, and soda-lime. Chemistry of decontamination.

No discussion was held on incendiaries since questions raised in the various laboratory sections has led to a thorough discussion of the chemistry of the termite-filled magnesium shell bomb, which is the only type whose chemistry differs totally from that of ordinary combustion. With these materials of areas 6 and 7, the work of the course was concluded.

CHAPTER VII

METHOD OF EVALUATION OF OUTCOMES

Consideration of Possible Means of Evaluation

Evaluation is the process by which one seeks to discover whether an educational effort has produced the changes in student behaviour which were intended. Evaluation instruments and procedures are designed for this purpose. Evaluation is not the process by which one finds out whether students know something. It is not the process by which the clever are distinguished from the stupid. It is not the process by which upright, conscientious, and hardworking students are identified and sent to the reward which their shiftless, irresponsible, and untrustworthy fellows clearly do not deserve.

All three of these processes which evaluation is not are unfortunately much more easily conducted than evaluation itself. Evaluation is, of course, impossible unless objectives are defined in terms of behaviour. If this seems too obvious to mention, one need only ask oneself what proportion of teachers conceive their function as one of changing students. Except for athletic instructors, who are expected to "Build Character" and "Develop a Sense of Good Sportsmanship," most teachers would regard such an act as an impertinence. Since changes are not sought, they cannot be defined, and if they are not defined, nobody can tell whether they occur or not.

Students, of course, do not expect to be changed either. Where education is directly concerned with a skill, this is not true. Students of typing expect to be taught to type. Students of welding expect to be taught to weld. But there is no agreement as to any action which should serve to distinguish students of history, English, physics, or mathematics from persons who have not studied these things, unless they become sufficiently proficient to make one of them a specialized profession.

It is perhaps strange that anything as costly as American education should be required to produce few specific results.

But all societies have institutions whose success in achieving their avowed purpose cannot be observed through verifiable change. Few church dignitaries would consent to deny Holy Communion to a random sample of their congregation in order to determine the efficacy of that sacrament, even if the challenging difficulties involved in determining who had been saved could be overcome. Education, in America, is a ritual--a ritual in which fealty to the middle class values of order, industry, verbality, and competition is demonstrated.

Like the small boy who rose in his pew and shouted, "Sold, American!" in the midst of a chanted mass, the educator who attempts to evaluate the achievement of the educative process intrudes practical considerations into sacred spheres. Of course, the church and the school both produce practical results. A church which produced no observable diminution in anxiety and tension among its congregation would soon lose its membership. A church which did not influence its lower class members to sedate and restrained modes of religious expression would rapidly lose status, being suitable, doubtless, to the tenancy of God but not to the very best people. But churches do not seek to evaluate their efficiency as psychotherapeutic or socially integrative agencies, since the avowal of such purposes would impair the function of the ritual through which the practical functions are discharged. Similarly, the schools which are in gravest danger of failure are not those whose students of French are graduated with atrocious accents, or whose economics majors destroy themselves like lemmings with each fluctuation in the stock market. It is those which do not find jobs for students, or which do not adequately respect the social and economic attitudes of their sources of income. But these crucial obligations, too, cannot be stated openly without destroying the ritual function of education in a democracy.

Furthermore, precise definition of purpose is not usually desirable in an enterprise which must draw wide popular support since the more clearly a purpose is understood, the more likely it is to arouse opposition. "Education for Democracy" is acceptable to most school boards. But if democracy is specifically defined to include equal employment opportunity for Negroes and Jews, government participation in problems like housing which involve private enterprise, and the abandonment of the right to coerce

one's children, very little support can be got for the program, since even those who are benefitted by one aspect of it will be offended by another. Even wars costing millions of lives and billions of dollars must now be fought with great care that no binding commitments be made as to their aims, lest the support of influential pressure groups be withheld.

It must, then, be understood that an educator who seeks to define course objectives in terms of behavior, and to design instruments to measure the degree to which those objectives have been attained, is attempting to place on education a novel and usually unwelcome responsibility. At a recent banquet which the motion-picture industry tendered itself in homage to its signal contribution to the late war effort, a spokesman referred to the motion picture as the greatest contemporary instrument for influencing human behaviour. This claim is probably justified, although the motion picture is rivaled by the concentration camp, which is particularly adapted to influencing the behaviour of persons unamenable to the gentler influence of the screen. The school can scarcely hope to rival either of these two social agencies; it is significant that neither depends, as the school still does, primarily on verbal stimuli to convey its message. Educational research, cannot be carried on, however, unless one is justified in assuming that education is a useful process, conducted for predicted purposes with measurable results. This assumption is in no way descriptive of the social role of education, but, taken as a statement of what can happen in the course of the educative process, it is quite true.

Not all difficulties in evaluation arise from the ritual nature of the school task. Formidable difficulties also arise from the diversity of behaviours required in carrying on the essential activities of human life. It is impossible to anticipate exactly what a person should be able to do in order to meet most effectively his particular difficulties, and to take fullest advantage of his particular opportunities. The most concrete definition of objectives in terms of behaviour will fall far short of the directions which a dramatic director would give to an actress with a complex role to interpret, and must clearly be somewhat categorical when applied to the behaviours of groups of human beings. This is not an insuperable problem in the planning of curricula, since people are commonly able to generalize learning

over an appreciable range, though transfer of training occurs less widely than was previously believed. In evaluation, since, whatever a person does, he does not do any of the other predictable things which he might also have done, the problem of validity is much more troublesome.

Still greater difficulties in evaluation are created by problems of observation. It has been many years since physicists proved mathematically that any method of observing a physical system must of necessity interfere with its operation, so that both the present and future status of the system could not possibly be completely known. This difficulty acts as a limiting condition in physical science, but as a constant harrassment in the social sciences. Behaviours sought through education can seldom be observed under conditions similar to those under which they are expected to be useful. The conditions under which they are observed influence them, often markedly. Indeed, there may be so little similarity between the life conditions in which the behaviour is considered appropriate and those under which it is examined that inference from the former to the latter seems scarcely justifiable. Or, differences may exist between the form of behaviour defined as an objective, and practical, apparently related forms which can be observed. This is particularly true in the case of long-range objectives, which, for purposes of evaluation, must be re-defined in terms of immediately observable behaviours.

Finally, in interpreting the results of evaluation, it must be recalled that processes involving persons can seldom be isolated as can those involving chemicals, especially where the issues involved are of the field of social sciences. In questions of criminal jurisprudence the problem has never been satisfactorily solved; extravagant and frequently fruitless precautions are taken to insure that the behaviour of juries is influenced only by admissible evidence presented at the trial. In education, no effort can be made to insure that learning will occur only through educational efforts; it is certainly clear that a student's curriculum is fortunately much wider than his course of study.

Evaluation must always take place under conditions which impose further limitations than these general considerations require. There are questions of the abundance and training of personnel, of expense, of time consumed in making and interpreting

records, of objectivity versus validity. There are questions of mores; Sheldon's¹ use of alcohol to distinguish the varieties of temperament from each other would have occasioned comment at Oklahoma A & M College. There are questions of roles; an instructor in continuous friendly contact with a group of students will be barred from the use of certain technics appropriate to an outside expert with no continuing relationship to the group.

But whatever inaccuracies or approximations are introduced, the purpose of evaluation remains the same: to determine to what extent a course has developed in students the behaviours it is designed to produce. Evaluation instruments should, therefore, be chosen so as to require, as nearly as is expedient, the display of these behaviours, under conditions similar to those with which the course was designed to deal. It is probably desirable to state at this point that evaluation, as defined in this chapter, and as used in the remainder of the dissertation, is concerned with the appraisal of success in reaching the objectives which the course defines for itself, rather than with determining whether those objectives are worthwhile. This question, in the author's judgment, is not susceptible of proof or disproof, since it can be answered only in terms of basic philosophical assumptions which cannot be verified. The validity of the assumptions of the needs approach and its range and applicability will be examined in the final chapters of the dissertation, but these chapters are not regarded as concerned with evaluation as the term is here used.

Several alternatives were available among the kinds of evaluation instruments which might have been used in the experimental program. These instruments, and the reasons for the final choices, will be briefly discussed below.

Paper and pencil objective tests; especially designed for the course.--Instruments of this kind bore the major burden of evaluation in the experimental course. Their design will be discussed in detail in the next section of this chapter. Items were carefully constructed so as to require as nearly as possible the behaviours which were the course objectives. All tests designed for the experimental group were objective, machine-graded instruments, which produced quantitative data with minimal clerical

¹W. H. Sheldon, The Varieties of Temperament, pp. 65-66. New York: Harper and Bros., 1942.

effort. Such measuring devices, of course, raise serious questions of validity in that the situation in which the behaviours tested are exhibited is utterly dissimilar to the life-situation in which they might be exhibited. Even if the mental processes involved in choosing a house-paint in an examination and in a store are the same, and they cannot be entirely so since the kinds of data available and the motivation are different, one does not indicate one's choice to the salesman by blackening a space on a sheet of paper. Such tests are nevertheless regarded by most workers as the most flexible, economical, and quantitative means of evaluation for general purposes.

Published, objective, paper and pencil tests.--Several nationally circulated tests are published, which are designed to meet the needs of teachers of conventional first-year chemistry courses. These do not, of course, measure the objectives of the experimental course, but are of value in determining the extent of overlapping between the objectives of conventional courses and the experimental course--the degree to which students in the one attain the objectives of the other. The American Council of Education Co-operative General Chemistry Test for College Students, Form 1942, was used for this purpose. This test was prepared jointly by the Co-operative Test Service and the American Chemical Society through its division of chemical education.

Student statements concerning course.--These are of great value in providing a qualitative estimate of the appropriateness of procedures and objectives, and a basis for inference as to the extent to which the course was emotionally accepted by the students--a highly important factor in determining the degree to which the course will influence behaviour. The way in which data of this kind were used is described in Chapter VI.

Follow-up studies of student behaviour in non-academic situations.--Data of this kind, extremely rare in educational research, are of the utmost value, for their validity cannot be questioned. It is particularly desirable to have follow-up data to support a contention that an experimental program is better adapted to the needs of students, but information of this kind is usually beyond the scope of a doctoral dissertation. Particularly, during wartime, follow-up investigations of student behaviour are not possible.

Anecdotal records of student behaviour.--Some information

of this kind, (the case of Irving) has been presented in Chapter V, as an example of information used in the development of the course method. Similar records were not made in the experimental group. Even those of the exploratory group are poor, being largely interpretation and inference as to personality. While the contacts which occur between instructor and student in college are too formalized and infrequent to be well-adapted to the writing of complete anecdotal records or case studies, such records can be made. That they were not made for the experimental group must be regarded as a deficiency in planning, resulting in part from a deficiency in training of the writer, who was not at that time skilled in the best objective technics for observing and recording human behaviour.

Analysis of materials written by students.--Student reports have several deficiencies as evaluation instruments. They are laborious to consider, and the information which can be obtained from them cannot usually be expressed in quantitative form for meaningful statistical operations. Since they are designed as instruments of instruction rather than evaluation instruments, the kinds of behaviours exhibited in writing them are seldom closely related to the course objectives, unless the development of skill in written expression is one of those objectives. Such reports, however, being long and coherent statements, can be made the basis for inference about student thought patterns and intellectual maturity, as well as examples of the capacity of students to apply chemical facts and principles to the solution of problems. They will be analyzed, and the results discussed in succeeding sections of the dissertation.

Opinions of experts.--Opinions of experts in science education are sometimes solicited in appraising experiments in that field. They are not of value, however, in determining the extent to which student behaviour is in accord with previously stated criteria. When course objectives are defined in terms of behaviour, opinions of experts do not appear to be relevant, unless the experts are so situated as to be able to observe students or their products.

Controlled observations of performance.--This technic is extremely valuable in determining the degree to which students have developed particular skills--laboratory technic, for example, or efficiency in locating books in a library. Where the behaviours

sought are not of the nature of technical skills, such observations do not appear to be applicable, and were not used in the experimental program.

The Design of Evaluation Instruments for the Experimental Course

Six examinations, three for each semester, were designed to measure progress toward the objectives of the experimental course. Each examination was completely objective and adapted to machine grading. In the next several chapters of the dissertation, items will be examined in detail and related to objectives in each area of need. In this chapter, it is desired that the general design of the instruments be considered.

No attempt was made to produce items of a particular kind. The influence of similarities in kind between course objectives and the arrangement made necessary by the design of printed answer sheets caused the items to be classifiable chiefly into three kinds:

1. Five response multiple-choice items intended to test the ability of the student to apply one or more chemical facts or principles to the solution of problems or portions of problems.--- These items had any number of correct answers from none to 5. Items with unique answers are usually preferred where neatness of statistical interpretation is a prime consideration, and these items might well have been superior had they been designed with only 1 correct answer. It was felt, however, that to provide only 1 answer uniformly would be artificial, and would prevent one from measuring the comprehension of a complete situation rather than a fragment of it. Examples of some of the 5 response multiple-choice items from the final examination of the first semester are given here. (All 6 examinations are included in Appendix A.)

A. Directions: In each of the questions asked or implied below, select those of the possible answers which are correct, and in the form on your answer sheet bearing the same number as the question, blacken the spaces having the same number as the answers. Each question may have any number of answers, from none to five.

1. If certain of the following statements were true of aluminum, it would be much less suitable for the manufacture of pots and pans that it is:
 1. If there were only half as many aluminum atoms in the world as there are.
 2. If aluminum did not become coated with a film of its own oxide when exposed to air.

3. If aluminum had 13 less protons in its nucleus.
4. If aluminum were less active than copper.
5. If aluminum lost electrons much more easily than it does.
2. Charcoal is used in water purification in order to:
 1. Destroy pathogenic organisms that may be in the water.
 2. Remove most odorous or colored impurities.
 3. Soften the water.
 4. Increase the epsilon potential of the water at the expense of the zeta potential.
 5. Show whether the bacterial content of the water has been reduced.
3. In the time required to heat an enameled saucepan containing its own weight in water to the boiling point of the water, an empty saucepan of the same kind heated over the same size flame might be ruined. Among the reasons why this is true are:
 1. A saucepan cannot be heated much above the boiling point of its contents for very long.
 2. The coefficients of thermal expansion of metal and enamel are not precisely the same.
 3. The specific heat of water is higher than that of most substances.
 4. Enamelware is attacked more rapidly by boiling water than by water at room temperature.
 5. The boiling of water consumes less than 100 cal./g.

2. Fifteen response matching sets, designed to test information as to the composition, properties, uses and characteristics of groups of similar materials.--

Below you will find a list of common alloys, followed by a list of descriptive terms which might apply to them. In each of the forms on your answer sheet bearing the same number as an alloy, blacken the spaces bearing the same number as the descriptive term which you think applies to that alloy. For example, if you are so cynical that you think sterling silver is mostly nickel, you will blacken space 3 in form 130. Any answer may be used any number of times, and any question may have any number of answers, or none. The term major constituent is taken to mean a constituent consisting of half or more of the total alloy, not merely an important constituent.

- | | |
|----------------------|---|
| 121. Woods Metal | 1. Major constituent is iron |
| 122. Aluminum Bronze | 2. Major constituent is copper |
| 123. Common steel | 3. Major constituent is nickel |
| 124. Invar | 4. Major constituent is magnesium |
| 125. Plumbers solder | 5. Contains much bismuth |
| 126. Nickel silver | 6. Contains much zinc |
| 127. Dow metal | 7. Contains much lead |
| 128. Ferrobullion | 8. Contains much nickel, but less than 1/2 |
| 129. Brass | 9. Is valued for its very low density |
| 130. Sterling silver | 10. Is valued for its low coefficient of thermal expansion. |
11. Is made from a common form of an unalloyed metallic element by oxidizing most of the carbon which is introduced as an impurity in the process by which this

- element is isolated from its ores.
12. Valued for its high magnetic permeability.
 13. Derives its usefulness from its low melting point.
 14. A very inactive alloy, not at all affected by the strongest non-oxidizing acids, but tarnishes rather easily.
 15. Made by replacing the tin used in one of the oldest of alloys by a metal much more recently made commercially available.

3. Complex items designed to measure (1) ability to distinguish between true and false statements of chemical fact related to a particular problem, and (2) ability to predict the influence of each fact, assuming it to be true.--The assumption is necessary, since without it, no uniform key for the response could be constructed. Five aspects of the problem were usually defined, and 15 statements given, to be classified as related or not related to these aspects.

Mrs. Gordon Esterhazy has been forced by the present servant shortage to assume managership of her own kitchen. Unfortunately, when the patriotic organization of which Mrs. Esterhazy is chairman launched its colossal scrap drive two months ago, she felt obliged to support this enterprise by donating all her kitchen utensils, and must now replace them. In doing so, she makes the following choices:

136. A copper teakettle.
137. An aluminum skillet for frying.
138. Cast iron pots and pans for boiling and stewing.
139. Enamelware vessels for pickling.
140. She refuses to purchase lead bowls for keeping cooked foods in the refrigerator.

Below you will find listed a series of reasons why Mrs. Esterhazy might have made these five choices. Some of these reasons are false, some are true. They bear two sets of numbers, 61-75, and 1-15. Looking at the first set of numbers first, please blacken the space marked T in the form on your answer sheet bearing the same number, if you believe the statement to be true, and the space marked F if you believe the statement to be false.

Then, no matter how you marked them, assume each statement to be true, and consider whether, in this case, it would have supported Mrs. Esterhazy in any or all of her five choices. If you believe that this statement, assumed to be true, would support Mrs. Esterhazy in one or more of her choices, blacken the space bearing the same number as the second number of the reason in the form bearing the same number as the choice.

For example, suppose there appeared below the following possible reason, with these numbers:

87-7 Cast iron can never be attacked by any sort of water solution. This is a false statement. You would therefore blacken space F, in form 87. However, if it were true, it would certainly be a good reason for the choice which Mrs. Esterhazy made in statement 138. Therefore, you would blacken space seven in form 138.

THE REASONS

- 61-1 The use of complex metal silicates as coatings for metalware results in a highly impervious and resistant utensil.
- 62-2 The oxide film with which aluminum becomes coated is easily attacked by hot grease.
- 63-3 Some metal ions are electrically neutral.
- 64-4 There are more protons in the nucleus of an iron atom than there are electrons in its outermost orbit.
- 65-5 Many soluble metal compounds can be ingested without harm.
- 66-6 The activity of certain metals is inhibited if silicon is present in its surface layer.
- 67-7 The salts of some metals are poisons whose effect on the body is cumulative.
- 68-8 Metals which are only slightly above hydrogen in the electromotive series may nevertheless react with water if given long enough.
- 69-9 Copper will drive silver ions from a solution containing them.
- 70-10 Hydronium ions will not occur in fats appreciably under the conditions of cooking.
- 71-11 Metals below hydrogen in the electromotive series cannot react with pure hot water.
- 72-12 Aluminum is too inactive to react with foodstuffs.
- 73-13 Coatings of mixed metal silicates are not susceptible to thermal fracture.
- 74-14 When a lead atom loses electrons, it becomes a lead ion.
- 75-15 Metals denser than aluminum can react only with strong oxidizing agents.

Other miscellaneous types of items, such as numerical problems, appeared occasionally, but do not constitute a distinct group. All examinations were subdivided, and a specific time allotted to each subdivision. Students were directed to proceed to the next subdivision if they completed one in less time than allotted, but not to spend more time than allotted on any subdivision. In this way, a fairly balanced performance on all parts of the examination was obtained from each student.

Student reaction to the examinations was mixed. At first there were many complaints as to the difficulty of the examinations, especially the items of type 3, which were difficult for students to understand until they grew accustomed to them. These complaints ceased, however, almost as soon as it became apparent that letter grades would not be assigned on the basis of an arbitrarily fixed percentage of a perfect score, as the students had feared. Nor did confusion continue; surprisingly, perhaps, the abstract mental operations required by items of type 3 appeared to be understood by all students after their first experiences with them. Items of this kind have, however, a decided "practice effect"; for this reason, in part, the differences in

performance between experimental and control groups were greatest on these items. The examinations, and the results obtained by their use, will be explained in detail in the next several chapters of the dissertation.

PART THREE

APPRAISAL OF SUCCESS IN MEETING THE MAJOR NEEDS

CHAPTER VIII

APPRAISAL OF SUCCESS IN MEETING

NEEDS IN AREA THREE

Brief Characterization of Area Three

Area 3, it will be recalled from the description in Chapter IV, concerns the student's need to be "an effective consumer of goods." It is a truism that all useful things derive their usefulness from their chemical structure; while it is not equally true that a knowledge of chemistry is necessary in order to purchase all kinds of things, it is certainly true that there are many commodities which cannot be chosen wisely without some acquaintance with their chemical properties.

Included within Area 3 were the following specific needs, which will be recapitulated here.

1. To choose suitable metalware for the plumbing system, kitchen utensils, and metal devices used in the home.
2. To choose and care for glassware and window glass in the home.
3. To choose suitable paints, varnishes, and lacquers to finish and protect the home and its contents.
4. To choose china, earthenware, and enameled articles for use in the home.
5. To choose and use wisely a fuel system for heating the home.
6. To choose a suitable structural material for the home.
7. To choose effective and safe antiseptics and disinfectants.
8. To choose dentifrices, shaving soaps, and other aids to an attractive personal appearance.
9. To use refrigeration facilities wisely and efficiently.

All the foregoing are specific needs to which chemistry may contribute, and the contribution of chemistry to the meeting of these needs is measurable by the kinds of evaluation instruments discussed in Chapter VII. As stated in Chapter VI, no students chose to study intensively the problems based on needs 2 and 4; these needs were briefly discussed in connection with other problems, however, and the ability to use chemistry to meet them

was measured by certain items on the examinations.

TABLE 2

DESIGNATION OF EXAMINATIONS PREPARED FOR EXPERIMENTAL GROUP

Examination	Designation	Administered to Control Group?	No. of Persons or Pairs Taking
First Examination Chemistry 134. . .	A	No	65
Second Examination Chemistry 134. . .	B	No	58
Final Examination Chemistry 134. . .	C	Yes	46
First Examination Chemistry 144. . .	D	No	32
Second Examination Chemistry 144. . .	E	Yes	14
Final Examination Chemistry 144. . .	F	Yes	8

Relation of Items to Specific Needs in Area Three

TABLE 3

RELATION OF ITEMS ON EXAMINATIONS TO
NEEDS LISTED FOR AREA THREE*

Examination	Items
Need 1	
A	1-15, 121-130, 136-138, 140
C	2, 3, 123-126, 129, 130
F	1, 3, 4, 19, 123-126, 129, 130
Need 2	
B	9, 123
C	121
F	121
Need 3	
B	7, 8, 10, 128-130
C	8, 15, 19, 122
F	122

TABLE 3--Continued

Examination	Items
Need 4	
A	139
B	11, 124, 126
C	127
F	127
Need 5	
B	136-140
F	20
Need 6	
B	15, 121, 122, 125, 127
C	13
Need 7	
B	1, 2, 4-6, 12, 14
C	7, 128
F	128
Need 8	
B	3
C	1
Need 9	
C	17, 18

* Only those items are listed whose results are actually used in the numerical data to be quoted.

It will have been noticed, perhaps, that some items on the examinations which might have been included on the lists have been purposely deleted. This is due to their appearing to be poor measuring devices, successful performance on which would have little relationship to the behaviours stated as objectives. Among the items so deleted were 61 to 75 of examinations A, B, C, and F; item 13 of examination B; and item 12 of examination C. Items 61 to 75 are true-false items forming a part of the complex group described as type 3 in Chapter VII. These played a useful part in structuring the complex items, but the actual behaviours to be observed are embodied in the portion of the item requiring the student to predict the influence of the statement, assuming it to be true, on the situation described. Items 13 of B and 12 of C are very similar numerical problems which could be classified under area 9, but which bear only the most academic relationship to the use of refrigeration facilities.

Evaluational Data

Two kinds of numerical data have been obtained in the course of the analysis of the results of the experimental group examinations. Those examinations which were administered to both experimental and control groups, as indicated in Table 2, provide the basis for a comparison of the achievement of paired individuals. Each student in the experimental group was matched to a student in the control group on the basis of the Iowa Placement Examination, New Series (Chemistry Aptitude) Form X, and the American Council on Education Co-operative Psychological Examination, 1939 edition. Where more than one control student was available whose scores on these two measures were similar to those of a student in the experimental group, scores on the American Council on Education Co-operative English Examination were used to choose between them. No student in either group had taken chemistry in high school. The mean score of the experimental group students on the Iowa test was 28.74; of the control group students, 28.91. A score of 28 on this examination corresponds to a percentile score of 20 in the published norms.

With students paired in this manner, the customary measure is the difference between the mean scores made by experimental and control groups. This measure will be used here; experimental and control group means, the standard error of the difference between the means of the two correlated groups, and the critical ratio of the difference between the two means to the standard error will be given for each need, and for total scores within each area of need, on each examination which contains items measuring needs within that area. The ratio may be interpreted according to the normal distribution for measurements made on examination C, which was administered to 46 pairs of students. Ratios on examinations E and F, administered to 14 and 8 pairs respectively, should be interpreted according to Student's t-distribution. All scores are uncorrected raw scores, consisting of total right answers chosen per student.

In dealing with the results of examinations A, B, and D, which were administered to the experimental group only, no comparison is possible. The most useful information to be gathered from these examinations is obtained by the examination of those responses correctly chosen by an arbitrary proportion of the students. This may be set at any figure desired, but it seems

reasonable to assume that items containing responses correctly chosen by one-half or more students measure learning undoubtedly resulting from course experiences.

The results on examination C for area 3 are presented in Table 4. On examination F, too few items pertaining to this area were represented to permit a meaningful measurement of differences between control and experimental group in meeting of individual needs within the area. The results on examination F for all items measuring needs in this area are as follows: Mean, experimental group, 13.375; mean, control group, 8.875; standard error of difference between means, 1.49; critical ratio (t), 3.02. With 7 degrees of freedom, a t ratio of 2.365 is significant at the 5 per cent level, while a t ratio of 3.449 is required for significance at the 1 per cent level. The t ratio is obtained in precisely the same manner as the ratios quoted in Table 6, but must be interpreted according to student distribution because of the small number of pairs involved.

TABLE 4
RESULTS OBTAINED ON EXAMINATION C IN MEASURING
OBJECTIVES WITHIN AREA THREE

Need	M_x	M_c	δ_{diff}	Z
1	6.348	2.435	0.528	7.411
2	1.457	0.891	0.140	4.036
3	3.130	2.130	0.254	3.937
4	0.978	0.304	0.124	5.435
5	-	-	-	-
6	0.913	0.457	0.162	2.820
7	2.217	1.239	0.193	5.064
8	1.370	0.870	0.161	3.102
9	2.239	1.957	0.214	1.317
Total. .	18.652	10.282	1.002	8.353

On examinations A and B, the items correctly answered by more than 50 per cent of the students will be summarized in Table 7. All such items on examination A measured ability to meet need 1 of area 3. With reference to items on examination B, Table 7 identifies the need measured by each item listed. Since most of the items have several correct responses, the table also identifies the particular one which more than half the students chose.

TABLE 5

CORRECT RESPONSES MEASURING NEEDS IN AREA THREE CHOSEN BY
MORE THAN HALF OF STUDENTS TAKING EXAMINATIONS A AND B

Examination A			Examination B			
Item	Response	% Choosing	Item	Response	% Choosing	Need Measured
1	4	83.1	1	5	88	7
5	1	61.5	2	4	78	7
6	1	58.5	3	1	56	8
6	3	58.5	3	2	56	8
12	4	60.0	5	2	61	7
13	5	76.9	5	3	61	7
15	5	73.8	6	3	80	7
123	1	76.9	7	5	68	3
129	2	67.7	8	2	63	3
137	12	63.1	9	3	76	2
140	7	66.2	10	1	74	3
			11	1	63	4
			14	1	56	7
			15	2	61	6
			122	8	58	6
			123	1	64	2
			123	8	56	2
			124	8	54	4
			125	6	57	6
			126	15	71	4
			130	9	53	3
			136	1	85	5
			136	7	56	5
			137	13	64	5
			138	2	53	5
			140	11	69	5

Likewise of interest are those correct responses made by fewer than one-fourth of the students taking these examinations. They are listed similarly in Table 6.

Interpretations

The data presented in Table 4 indicate a statistically significant superiority for the experimental group, as usually interpreted, with respect to all needs except need 9. The observed superiority of the experimental group in its ability to "use refrigeration facilities wisely and efficiently," as predicted by the items of examination C, might easily be due to chance. A critical ratio of 1.317 indicates that the dif-

TABLE 6

CORRECT RESPONSES MEASURING NEEDS IN AREA THREE CHOSEN BY
LESS THAN ONE-FOURTH OF STUDENTS TAKING
EXAMINATIONS A AND B

Examination A			Examination B			
Item	Response	% Choosing	Item	Response	% Choosing	Need Measured
2	2	6	1	1	15	7
6	4	20	1	3	14	7
6	5	25-	2	2	22	7
12	3	25-	2	5	19	7
121	7	3	4	5	12	7
121	13	20	11	2	7	4
122	15	23	12	5	24	7
124	1	23	14	5	17	7
124	8	3	121	1	15	6
124	10	15	121	2	3	6
126	2	15	121	8	14	6
126	6	0	121	10	0	6
127	4	23	121	14	7	6
127	9	15	122	1	17	6
129	6	12	122	2	8	6
136	11	23	122	10	0	6
136	15	9	124	2	7	4
137	5	8	124	10	7	4
137	10	23	124	14	14	4
138	6	12	126	1	17	6
139*	13	23	126	2	14	6
			126	10	3	6
			126	14	2	6
			128	3	10	3
			128	14	17	3
			129	10	20	3
			129	14	2	3
			136	15	23	5
			139	5	7	5
			139	9	5	5
			140	5	14	5

*Measures need 4.

ference would be expected to occur 9 times out of 100 from chance alone; too frequently, certainly, to prove real superiority. The next critical ratio in Table 4, in ascending order, is that for need 6, 2.820. This would occur only about twice in 100 times on a chance basis, while 3.102, for need 8, would occur just less than once in 100 times. The remaining ratios are so large as to amount to practical certainty that the experimental group is

superior. While they vary considerably in size, it should be remembered that these numbers are not a measure of the magnitude of the superiority of the experimental group, but of the certainty that the superiority is real and not a result of chance factors.

The poor achievement on need 9 is, in the writer's opinion, due to the highly abstract behaviours selected as establishing student achievement of this objective. Items 17 and 18 of examination C both require the ability to recognize a relationship expressed in very abstract thermodynamic terms. They are probably highly inappropriate for students at the 20th percentile of the Iowa aptitude test--the average position for both experimental and control groups. Needs 6 and 8 are measured by single multiple choice items, which require behaviours much more similar to those by which the control group was accustomed to be evaluated than do the complex items included among those by which the remaining objectives are evaluated.

The data in Tables 5 and 6 do not lend themselves to as obvious interpretation, but are quite illuminating, especially as to the appropriateness of the behavioral level at which the course objectives were defined. While no one would deny that a student needs to be an effective consumer of goods, and perhaps few would deny the validity of the specific needs into which the area has been broken, there is certainly room for considerable question as to just what behaviours should be sought as an indication that the student can use chemistry to meet the specific needs listed. As indicated in Chapter VII, evaluation is essentially a process of inspection whereby one determines whether the behaviours defined as the course objectives have been reached by students, and the construction of evaluation instruments is actually the designing of situations in which such behaviours, if developed by the student, will be displayed. The behaviours in terms of which objectives are defined may vary from those appropriate to the grade-school to those appropriate to graduate study, without altering the validity of the need to which they are related.

The data in Tables 5 and 6 cast grave doubts on the appropriateness to the course clientele of the behaviours used to define student needs. Indeed, this is the chief information which they reveal. Table 5 shows clearly that, except for need 9, which the comparative data from examination C have already shown to have been inadequately met, some items measuring all needs in

the area were successfully passed by more than one-half of the students. There is no need measured in the area, other than 9, which chemistry does not help more than one-half of the students to meet.

But it is also apparent that, despite the fact that all but one of the needs of the area are included among those measured by these "majority items," a relatively small fraction of the total number of possible responses on examinations A and B were passed by more than half of the students. Responses from exactly one-third of the items of examination A were so chosen, while responses from 72 per cent of the items of examination B were chosen. This amounts to 17 per cent of the total possible correct responses on examination A, and 31 per cent of the possible correct responses on examination B.

Correct responses from 43 per cent of the items on examination A, and 50 per cent of the items on examination B were correctly passed by less than one-fourth of the students; this amounts to 33 per cent of the total possible correct responses on A, and 37 per cent of the total possible correct responses on B. Thus, a larger proportion of the course objectives for this area, whether counted as items or correct responses, were reached by less than one-fourth than by more than one-half the students. Finally, items 6, 12, 129, and 137 of A, 1, 2, 11, 14, 122, 124, 126, 136, and 140 of B contain certain correct responses which were chosen by less than one-fourth of the students, and others that were chosen by more than one-half.

Examination of the items themselves¹ reveals that, quite consistently, it is concreteness, directness of relationship, and, occasionally, no doubt, past familiarity which makes a concept easy to pass on an examination, rather than the particular content material being examined. Thus in item 1 of question 6 in examination A the statement "Few metals will corrode if kept perfectly dry" is obvious to nearly anyone, while response 2 of this item, "Hot water is more corrosive to metals than cold," sounds untrue on a general basis, unless one specifically understands that the rate of a chemical reaction is accelerated by heat and that the ionization constant of hot water is larger than that of cold water. While both these concepts were discussed in class,

¹Appendix A.

the second, at least, is quite obscure and the first rather abstract. Response 3, "It is the hydronium ions which are responsible for most corrosion," is perhaps the simplest generalization about the dynamics of corrosion which can be made, while response 5, "The corrosion of metals by water results in the introduction of metal cations into the water," is a very abstract generalization and a rather complex one. On item 12, the statement, "Small traces of impurities greatly impair the conductivity of copper wire," is concrete but is surely a far less familiar concept than "A copper wire is a better conductor of electricity than an aluminum wire of the same cross-sectional area"; furthermore, the necessary qualifying phrase ". . . of the same cross-sectional area" is the kind of thing which often seems to act as a clue on examination items.

On item 123 of A, it is quite plain that few students need have learned anything from the course in order to identify iron as the major constituent of steel, while response 11 on this item is so long and complicated that even the Collector of Internal Revenue might feel some hesitancy about using it. Similarly, on 129, brass is much more frequently associated with copper in the public mind than it is with zinc, if only because of its color.

On item 137, the relationship of such a statement as "Aluminum is too inactive to react with foodstuffs" (response 12) to the choice of aluminum kitchenware is clear; the relation of the statement, "Many soluble metal compounds may be ingested without harm," (response 5), is much more abstract and subtle. Likewise, response 10, "Hydronium ions will not occur in fats appreciably under the conditions of cooking," requires perception of an external relationship, as well as recall of the role of hydronium ions in corrosion.

While the same factors are involved in the differences observed in choice of responses on examination B, they seem to be related more closely to content rather than to the general degree of abstraction, comprehensibility, and familiarity alone. With reference to item 1, it is difficult to see why merthiolate should be more easily recognized as an antiseptic than sodium hypochlorite or metaphen, but it was; sodium hypochlorite, of course, is not often sold as such, while merthiolate invariably is. Clearly, these students do not recognize the bactericidal function of sodium hypochlorite, since on item 14 also it is chosen as an

oxidizing antiseptic by less than one-fourth of the students, while hydrogen peroxide is recognized by slightly more than half. Familiarity seems to be the factor here, as peroxide is also marketed under its own name. Again, in item 2, quinine is more familiar to the Oklahoma farm boy than salvarsan or sulfathiazole, though there is certainly no difference in abstractness or subtlety here. On item 11 the statement that earthenware cups are ". . . fired at a low temperature" is easier to understand than the statement that they are ". . . less completely converted to fused silicate in the course of manufacture."

Items 121-130 are somewhat different in that they have a great many correct responses, some of which are, in a sense, fortuitous; that is, they consist of statements included in the matching list to serve as responses for a particular item or items, but which must nevertheless be counted as correct answers to other items in the group. Thus response 10, "Contains an opaque solid like ferric oxide or basic lead carbonate," is intended for items 128 and 129, "paint" and "lacquer," but must also be accepted as a response for 122, "brick"; 124, "china"; and 126, "earthenware." It is hardly surprising that it is chosen by less than one-fourth of the students as a response for these items. Response 14, also rejected by more than three-fourths of the students for items 124, 126, and 128, is very long, abstract, and complex and probably was not understood. On the other hand, the fact that more than one-half of the students chose response 8 for items 122, 123, and 124, does not seem especially satisfying, since the use of heat in the manufacture of brick, glass, and china, seems very obvious. Curiously, less than one-fourth of the students chose this response for item 121, "Portland cement," although this also "must be heated to a very high temperature in the course of its manufacture"; the fact is more obtrusive, however, in thinking of a ceramic material.

Results on items 136-140 are more gratifying, since here the correct responses chosen by more than one-half the students seem to be definitely more closely related to the problem situation than those which are chosen by fewer--particularly than those chosen by less than one-fourth. Since this group is long and so intricate that selections from it placed out of context would be very difficult to interpret, the reader is referred to Appendix A for samples of the material. Despite its abstract nature, a

considerable part of it seems to have been handled satisfactorily by the students, as the results in Tables 5 and 6 show.

There are, of course, many other items listed in these two tables which have not been discussed here, though all the items which appear in both tables have been considered in detail. If the reader is interested in the exact nature of these items he may identify them easily by reference to Appendix A. The data analyzed, however, seem to justify the following conclusions:

The experimental group demonstrated a statistically significant superiority to the control group on all measured needs within area 3, except 9, and on the area as a whole.--This superiority on the area as a whole was again demonstrable at the end of the second semester, although not enough items measuring these needs were included on the second semester final to permit an inference to be drawn as to the continuation of superiority need by need.

Items measuring the use of chemistry to meet all needs except need 9 were successfully passed by more than half of the students on the examinations administered only to the experimental group.--Items passed by less than one-fourth of the students were also found scattered among most needs within the area.

The behaviours in terms of which the course objectives are defined were not as a whole appropriate to the students to whom the course was offered.--Even though they seem to be valid examples of the use of chemistry to meet the needs which form the basis of organization of the course, many of them are not the kinds of behaviours by which most such students may be expected to use chemistry to meet their needs. If the course objectives are to be reached by most of the students, they must be redefined in terms of behaviours requiring use of less abstract symbols, appraisal of fewer simultaneous complex factors, and, perhaps, a less complete degree of information.

Not content, but such factors as familiarity, comprehensibility, and concreteness seem to distinguish the responses chosen by more than half the students from those chosen by less than one-fourth.--Items containing responses of the former group are found among all the needs with reference to which the experimental group is demonstrably superior, and items of the latter group are found among most of them, while on many items responses of both groups exist side by side. Internal factors, rather than the content of

the objective measured are therefore chiefly responsible for the ease or difficulty with which the item can be answered by students.

CHAPTER IX

APPRAISAL OF SUCCESS IN MEETING NEEDS IN AREA FOUR

Brief Characterization of Area Four

Area 4 is concerned with the student's need to support necessary public services intelligently. There are many requirements of civilized life, as Americans understand the term, which cannot be fulfilled at the discretion of single individuals, and which are usually met by organized action on governmental authority. The scope of such activities has, of course, increased widely in the past 50 years, and growth appears to be increasing even more rapidly today. In the laissez-faire state of the nineteenth century, few needs would have been included under area 4; in a social-service state it is conceivable that area 1 and much of areas 5 and 6 might be subsumed under it as medical care, full employment, and recreational opportunity came to be regarded more and more completely as public responsibilities.

At the present time there are, of course, numerous functions which are so commonly regarded as governmental that there is no serious proposal that they be discharged by private agencies. Several of these require the application of considerable chemistry, and it is presumably necessary that this chemistry be understood by the citizen if he is to appraise the character of the services offered him and determine whether they are as adequate in scope as resources and technology permit. The particular services to which it was assumed the student should be able to apply chemistry were listed in Chapter IV. They will be recapitulated here. The student needs:

1. To support effective community procedures for the purification of water.
2. To support effective rural or urban procedures for sewage disposal.
3. To support effective community procedures for the detection of crime.
4. To help conserve critical materials needed in the war effort.

5. To support effective community procedures for the prevention and extinction of fires.
6. To support the maintenance and enforcement of pure food and drug legislation.
7. To use effectively the protection provided by official standards of weight and measurement.
8. To support wise choices of materials for highway construction.

Needs 7 and 8, it will be recalled, were deleted because of lack of expressed student interest, while progress toward need 4 was not evaluated because the instructional materials for it were presented by guest speakers who were not available during the period when the materials for area 4 were being presented. Comparative data on the achievement of the remaining 5 needs by experimental and control groups will be presented.

Relation of Items to Specific Needs in Area Four

The items measuring each need in area 4 are identified in Table 7. Examinations bear the same key letter as in Table 2.

TABLE 7

RELATION OF ITEMS ON EXAMINATIONS TO NEEDS LISTED FOR AREA FOUR

Examination	Need 1	Items
C	6,	10, 16, 20
F	13	
	Need 2	
C	11	
	Need 3	
C	4,	5, 9
F	11	
	Need 5	
C	14	
	Need 6	
C	46-53	

Evaluational Data

All of the items evaluating student achievement in area 4 are taken from examinations which were administered to both ex-

perimental and control groups. All the data thus obtained may, therefore, be interpreted comparatively.

On examination F, as reference to Table 7 shows, only 2 items, each pertaining to a different need, measure the objectives of area 4. This examination was administered to only 8 pairs of students. There is probably very little to be gained by computing results from such scant data, but the writer has done so in order to make the series of available measurements as complete as possible. The following results were obtained: M_x , 2.875; M_c , 3.125; 6_{diff} , .458; Z , .525. This shows superiority for the control group, although not a statistically significant one. In a chance distribution of differences about 60 per cent would exceed this critical ratio.

The results obtained from examination C, broken down need by need and for the area as a whole are presented in Table 8.

TABLE 8

RESULTS OBTAINED ON EXAMINATION C IN MEASURING
OBJECTIVES WITHIN AREA FOUR

Need	M_x	M_c	6_{diff}	Z
1 . . .	3.152	1.565	0.258	6.251
2 . . .	1.326	0.717	0.146	4.172
3 . . .	3.630	3.348	0.266	1.064
4 . . .	-	-	-	-
5 . . .	1.261	1.065	0.118	1.661
6 . . .	1.717	0.543	0.218	5.385
Total .	11.087	7.239	0.541	7.109

Interpretations

The results obtained on area 4 clearly differ quite markedly from those obtained on area 3, since the 5 needs fall into 2 sharp groups--a group of 3 on which definitely significant superiority of the experimental group is obtained, and a group of 2 on which the superiority of the experimental groups is as obviously not significant. There are about 5 chances in 100 that the critical ratio obtained for need 5 could have arisen from chance alone, and about 15 chances in 100 that the critical ratio for need 3 could have arisen from chance alone. No confidence can

therefore be placed in the reality of differences of so small a magnitude. But the ratios obtained on needs 1, 2, and 6 provide practical certainty of real superiority of the experimental group. This situation is all the more striking in that need 3 is measured by 3 items, while need 2 is measured by only 1. Furthermore, all the items are of the same general kind--five-response multiple choice items. There seems no doubt, therefore, that the observed variation in the degree to which the objectives in this are have been obtained is a meaningful variation rather than an artifact introduced in the process of evaluation.

In order to get more information on the basis of which this distribution might be explained, it is desirable to examine the responses on examination C which were chosen by more than half of the students in each group. These data, which will be presented in Table 9, are based on the total group taking the examination (81 members of the control group and 58 members of the experimental group) rather than on the 46 pairs of students who provide the data for Table 8, but should provide an adequate picture of the basis for differences between the two groups.

TABLE 9

RESPONSES ON EXAMINATION C MEASURING NEEDS IN AREA FOUR
CHOSEN BY MORE THAN HALF OF THE STUDENTS
IN EXPERIMENTAL OR CONTROL GROUP

Item	Response	% Choosing - Experimental Group	% Choosing - Control Group	Need Measured
4	1*	66	6	3
5	1	95	79	3
5	2	43	53	3
5	5	62	60	3
9	2	83	26	3
9	4	57	56	3
6	2	79	41	1
11	1	72	38	2
11	2*	31	53	2
11	4	58	25	2
14	1	86	89	5
47	2*	53	16	6

*Erroneous response.

Of the 7 items listed in Table 9, only item 11 functioned

in the classical manner to separate experimental and control groups. Its capacity so to function is the evident reason why a significant difference between the two groups with reference to need 2 could be obtained, even though only this single item measured the ability of students to meet need 2. If item 11 is a valid measure of the ability of students to apply chemistry to the problem of sewage disposal, there seems to be no reason to doubt the superiority of the experimental group with respect to this need.

With reference to need 1, the situation is less dramatic. Only 1 response on any of the 4 items was chosen by more than half of the students in either group; this response measures the understanding by students of the function of charcoal in water purification. While the datum on this response favors the experimental group, it is clearly insufficient to explain the critical ratio of 6.251 obtained for this need. Evidently there is consistent, small superiority of experimental to control group on the several items measuring capacity to meet need 1.

It is equally clear that there is no real superiority of the experimental group on need 3--rather an unpleasant fact to face, since this need was as thoroughly emphasized as any in the area, having a special laboratory experiment (Experiment I) and a special reference work (Forensic Chemistry), both of which seemed to be of interest to students. Yet, among the responses measuring the ability to apply chemistry to the detection of crime which were chosen by more than half the students of one of the two groups, one which is erroneous strongly attracted the experimental group but was passed over by the control group; one which is correct was chosen by a majority of the control group but not of the experimental group; and two which are correct were chosen by so nearly the same percentage of both groups as to indicate no real superiority for the experimental group. The first of these, (4,1), is apparently the result of partial learning; the experimental group had learned to associate silver halides with photography, without learning their precise role, and so were trapped by a distractor which did not operate effectively against the uninstructed control group. The second, (5,2), the writer attributes to a rather curious cause. In connection with the crime-detection topic, great effort had been made to emphasize that no scientific procedure exists by which the blood of particular in-

dividuals, or members of racial groups, could be distinguished; it was felt that the racial conflicts existing in Oklahoma as a border state justified one in attaching great importance to this fact. This learning appears to have carried over to cause certain of the students to believe that human blood could not be identified as such by laboratory test, although an uninstructed person might easily assume, correctly, that it could. This explanation seems to be supported by the fact that not a single experimental group student chose the response on item 5 which would indicate belief that the blood of a particular individual could be identified by scientific test.

Correct responses (5,5) and (9,4) which were chosen by approximately equal majorities of both groups are rather difficult to explain. The first of these, which requires recognition that the blood of persons of different blood groups can be distinguished by laboratory test, is probably so obvious as to require no particular knowledge of members of either group, and might therefore measure no results of instruction. The second, requiring recognition of the role of ultra-violet radiation in the detection of forged documents, does not seem to be either obvious or a matter of common knowledge, and the writer knows no reason for the notably successful performance of the control group on this response, especially since (9,2), dealing with alterations in inks through aging, provides the most favorable contrast between experimental and control groups of any item measuring needs in area 4.

Response (14,1), the only response measuring need 5 which was chosen by a majority of either group, was successfully passed by large majorities of both groups--slightly larger in the case of the control group than the experimental group. There is a clear chance that the presence of this response alone prevented the achievement of a significant superiority by the experimental group with respect to the ability to apply chemistry to the problem of prevention and extinction of fires, since the response not only deals with a relationship--oxidation versus combustion--which is too obvious to distinguish between the two groups, but is chosen by so many persons as to swamp the effect of the more discriminating but less popular response (14,3). This response was chosen by 36 per cent of the experimental group, as compared to 15 per cent of the control group, and the case for need 5 rests

on these responses alone. The critical ratio for need 5 is fairly high, and may possibly be significant.

The only response measuring need 6 which was chosen by a majority of either group is (47,2), an erroneous response whose confusing character probably arises, as intended, from difficulties encountered by students in distinguishing the concepts of molar and normal concentration. Despite this source of inferiority, the over-all results of the battery of items measuring need 6 indicate clear superiority for the experimental group on this rather abstract and quantitative material; the superiority is evidently composed of many small superiorities on the several items, rather than overwhelming success on any single item.

The foregoing data appear to justify the following conclusions:

The experimental group exhibits marked superiority to the control group in its ability to apply chemistry to the purification of water, and in its understanding of the stoichiometric basis of standards for food and drug inspection.--The items measuring the latter understanding, however, are open to criticism on the grounds that they are relatively more remote, in the behaviours which they require, from need 6 as stated than the items measuring any other need in this area.

The experimental group exhibits dramatic superiority to the control group on the several responses of item 11, measuring the ability to apply chemistry to sewage disposal.--While the statistical significance of the differences exhibited on this item is not open to question, the reliability of a measurement based on a single item must be. This item, however, seems quite good both in the concreteness of the issues raised and their relation to rural rather than urban technics of sewage disposal.

The experimental group is evidently not superior to the control group in its ability to apply chemistry to the detection of crime.--This failure is not fully explained, but appears to be due in part to erroneous transfer of learnings from specific to general situations; that is, failure to recognize precisely what happens chemically in the developing of photographs or testing of blood, while becoming oversensitive to the names of substances or relationships involved in the process at some point.

The experimental group cannot be demonstrated to be significantly superior to the control group in its ability to apply

chemistry to the problem of fire prevention and extinction.--This failure may, however, be an artifact resulting from poor construction of the single item measuring the capacity to meet this need.

The experimental groups is undeniably superior to the control group in its ability to apply chemistry to the support of necessary public services as a whole.--The critical ratio for area 4 is larger than that for any single need within the area.

CHAPTER X

APPRAISAL OF SUCCESS IN MEETING

NEEDS IN AREA FIVE

Brief Characterization of Area Five

Area 5 is concerned with the student's need to earn a living. Since the students to whom the experimental course was being offered were students in the school of agriculture, all expected to earn their living through the practice of agriculture or allied technical skills. The problem of earning a living was to them, therefore, an agricultural problem.

In applying chemistry to agricultural problems one finds it convenient to classify the problems into several areas of content which have become classical as a partial basis for organizing the offering of schools of agriculture. Those problems appropriate to a course in inorganic chemistry may largely be classified as related to (1) dairy, (2) pest control, and (3) soils. The major area of foods and nutrition which is highly chemical in nature is replete with problems which require the use of organic chemistry for their solution, but inorganic chemistry has little to contribute to them.

In Chapter IV, the needs to which the course is expected to contribute in area 5 are specifically stated. Those which, when offered as problems, survived the process of student selection, became the basis of course discussion, and the ability to apply chemistry to their solution was measured. One need (need 2, dairy subarea) was so evaluated although the corresponding problem was not discussed separately; it was felt that the discussion of related problems had possibly contributed enough to the meeting of this need to justify the measurement. The needs with reference to which evaluational data are available are recapitulated here:

Subarea 1: Dairy; the control of pests. The student needs:

1. To prevent the development of undesirable flavors and odors in dairy products.
2. To control the production of foodstuffs dependent on bacterial action, such as buttermilk and cheese.

4. To handle milk and cream in such a way as to maintain stability; to use effective technics of homogenization, or, conversely, churning, where appropriate.
6. To control factors affecting the quality of frozen dairy products.
7. To control insects which attack farm crops and produce.

Subarea 2: Soils. The student needs:

1. To control soil texture for most effective plant culture.
2. To plan his farm in accord with the relationship between cropping, soil composition, and animal or human nutrition.
3. To provide essential soil constituents from external sources when natural processes cannot be expected to replace them.
4. To determine whether his soils contain all elements needed for plant growth, and provide for possible deficiencies.
5. To use agricultural by-products of little market value as effective soil amendments.

Relation of Items to Specific Needs in Area Five

The classification of items measuring ability to meet needs in area 5 is presented in Table 10.

TABLE 10
RELATION OF ITEMS ON EXAMINATIONS TO NEEDS
LISTED FOR AREA FIVE

Examination	Items
Need 1	
D	1
Need 2	
D	15
Need 4	
D	2-8, 11, 121-124, 126-128
F	2, 5
Need 6	
D	9, 10, 12, 13
F	6
Need 7	
E	10, 12, 123, 124, 131-140
F	131-133, 135, 136, 138

TABLE 10--Continued

Subarea 2

Examination	Items
Need 1	
E	123, 124
Need 2	
E	1, 126, 127, 130
Need 3	
E	3, 4, 8, 128
Need 4	
E	2, 5, 6, 9, 13-15, 121, 122, 125, 129
F	7, 8, 12
Need 5	
E	11

Item 9 of examination F, though originally intended to measure need 4 of subarea 1, is omitted from the source of data to be cited with reference to the meeting of this need. It is not at all closely related to the need, and since several items measuring need 4 are available, it was felt that the inclusion of item 9 would decrease the precision of measurement.

Evaluational Data

Data on the ability of the students to use chemistry to meet needs related to dairy farming are obtained from examination D, which was administered to the experimental group only, and examination F, which was administered to both experimental and control groups. Data on the ability to use chemistry in pest control and on problems related to soils are obtained from examinations E and F which were administered to both experimental and control groups. For area 5, as for area 3, there will be two kinds of data: comparisons between matched groups, and, for the dairy problems, quantitative examination of individual test items as with examinations A and B.

Correct responses correctly chosen by more than half the students taking examination D are listed in Table 11. Needs cited are all from subarea 1 of area 5.

TABLE 11

CORRECT RESPONSES MEASURING NEEDS IN AREA FIVE CHOSEN
BY MORE THAN HALF OF STUDENTS TAKING EXAMINATION D

Item	Response	% Choosing	Need Measured
1	1	65	4
3	1	77	4
5	2	58	4
6	5	81	4
8	3	77	4
9	1	58	6
9	3	71	6
10	5	58	6
11	1	77	4
12	2	65	6
12	5	84	6
126	4	58	4

Correct responses chosen by less than one-fourth of the students are listed in Table 12.

TABLE 12

CORRECT RESPONSES MEASURING NEEDS IN AREA FIVE CHOSEN
BY LESS THAN ONE-FOURTH OF THE STUDENTS
TAKING EXAMINATION D

Item	Response	% Choosing	Need Measured
3	4	16	4
7	2	23	4
15	1	16	2
122	13	23	4
122	15	16	4
123	2	10	4
123	7	10	4
123	9	10	4
126	10	10	4
126	11	6	4
126	14	13	4
127	1	23	4
127	9	3	4
127	12	23	4
128	15	3	4

The comparative data for experimental and control groups

are presented in Table 13. In this table, separate total scores are presented for items measuring dairy problems, and for the soils subarea, as well as for the area as a whole.

TABLE 13

RESULTS OBTAINED FROM EXAMINATIONS E AND F IN MEASURING OBJECTIVES WITHIN AREA FIVE

Need	Examination E				Examination F			
	M_x	M_c	$\bar{d}_{diff}$	t	M_x	M_c	$\bar{d}_{diff}$	t
Dairy Subarea								
1	.....	.....	.....	.....	.....	.....	.....	.....
2	.....	.....	.....	.....	.....	.....	.....	.....
3	.....	.....	.....	.....	.....	.....	.....	.....
4	.....	.....	.....	.....	1.750	1.875	0.466	-0.269
5	.....	.....	.....	.....	.....	.....	.....	.....
6	.....	.....	.....	.....	1.000	0.625	0.249	1.50
Total	.....	.....	.....	.....	.....	.....	.....	.....
4 & 6	.....	.....	.....	.....	.....	.....	.....	.....
7	13.071	8.214	1.329	3.657	2.750	2.500	0.493	0.507
					7.375	5.750	0.777	2.09
Soils Subarea								
1	2.286	1.143	0.512	2.232	.....	.....	.....	.....
2	4.286	1.929	0.487	4.840	.....	.....	.....	.....
3	4.643	1.500	0.545	5.788	.....	.....	.....	.....
4	8.857	5.144	1.116	3.328	3.000	2.375	0.779	0.803
5	2.429	1.286	0.177	6.450	.....	.....	.....	.....
Total	22.500	11.000	2.272	5.062	.....	.....	.....	.....
Total	.....	.....	.....	.....	.....	.....	.....	.....
Area	.....	.....	.....	.....	.....	.....	.....	.....
5	35.571	19.214	3.245	5.041	13.125	10.625	0.965	2.59

Interpretations

Only 2 of the 4 needs related to dairy farming are represented by items on examination F. While the other 2 needs are represented by items on examination D, only 1 such item is available for each need, and neither of these items contains correct responses chosen by more than one-half of the students taking examination D. Quantitative data as to the ability of the students to apply chemistry to needs related to dairy farming is

therefore restricted to needs 4 and 6, except for such inferences as may be drawn from the presence of (15,1). This response, which measures need 2, is among the correct responses chosen by fewer than one-fourth of the students.

Contrary to the case in examinations A and B, there are only 2 items on examination D containing correct responses chosen by both less than one-fourth and more than one-half of the students. These are items 3 and 126. Item 3 reads:

Among the important buffers found in milk are:

- | | |
|---------------------|---------------------|
| 1. HPO_4^- | 4. HCO_3^- |
| 2. HSO_4^- | 5. CN^- |
| 3. Cl^- | |

Responses 1 and 4 are correct. There seems no reason why response 1 should be so much more easily made than 4; the bicarbonate ion is, if anything, the more familiar of the two. Only one more student chose response 4 than response 5; apparently, if dairy cows were dependent on these students for guidance in conducting their metabolic processes their life would not be a very good risk. Item 126 is one of a complex group of three dealing with acid-base relationships and pH; the student is asked to appraise the influence of certain factors in causing the acidity of a solution to be reduced. Response 4, "The lactate ion is a fairly strong base," has the most obvious possible relationship to this problem, while response 10, "The hydrogen ion concentration of the original buttermilk. . . would be 1.6×10^{-10} ," is very subtly related, since it merely establishes that lactic acid is a weak acid and subject to buffer action. Response 11, "A solution of sodium lactate always contains some lactic acid molecules," is similarly devious in its relationship. Response 14, on the other hand, should have been much easier; the statement, "Lactic acid-lactate ions mixed constitute a buffer pair," is a matter of direct definition.

The most obvious difference between the responses chosen by more than half the students and those chosen by less than one-fourth is that all but one of the former are taken from the relatively simple multiple choice items in Part One of examination D, while all but 3 of the latter are taken from the complicated and abstract items of Parts Two and Three. There is, indeed, serious question as to the appropriateness of these two groups of items as instruments for measuring the ability to apply chemistry to the problems of dairy farming. Part Two is really nothing but

a very complicated exercise in the ability of the student to perceive the effects of changes in ionic concentrations on acid-base equilibria in solution; the fact that the solution is called buttermilk, and that acid-base equilibria have important influences on the processes of the dairy industry is not sufficient to make this a problem which dairy farmers will need to solve. Part Three is almost, if not quite, as bad. The situation is as complicated and abstract as that in Part Two, but it does deal with colloidal relationships which actually exist in milk. Items 121, 122, 123, and 124 deal with the chemistry of milk, but it is difficult to justify them as dealing with insights which the dairy farmer must have in order to conduct his business successfully. The level of understanding is clearly too high; these items deal with concepts which would be perfectly appropriate to colloid chemists engaged in the study of milk, but hardly necessary to young dairy farmers. Among the items of Part One it appears that the factors of concreteness and directness of relationship, which seemed most important in distinguishing easy responses from difficult ones on examinations A and B are equally effective on D. Many of the successfully chosen responses deal with chemical theory, but it seems always to be with aspects of theory which may be applied directly to the problem. For example, the choice of response 3 of item 8, "salts," as the constituent of milk which exerts the greatest effect on the freezing point, is a direct application of the elementary theory of electrolytes. Responses 1 and 3 of item 9, "Crystals of virtually pure ice are formed," and "The liquid portions remaining become more and more concentrated," are things that happen "when milk is frozen" as an immediate consequence of the behaviour of solutions. On the other hand, response 1 of item 15, "Alteration of small particles by reaction with other substances is more rapid than with large particles," is an abstract and rather remote reason why "homogenized milk often makes a very bad cheese," and as such is chosen by fewer than one-fourth of the students. Response 5 of this item, "Homogenization retards rate of coagulation," which sounds much simpler, was chosen by 65 per cent of the students, although it is not a correct response. Response 2 of item 7 which deals with the effect of oxalate ion on the rate of coagulation of milk ("Coagulation is prevented by the removal of the calcium") seems quite simple; the writer is surprised to find it chosen by only 23 per cent of the students.

The only comparative data available for the dairy problems is derived from 3 items on examination F, 2 of which are related to need 4, and 1 of which is related to need 6. The data for the 2 needs and their combined total, as derived from examination F, are presented in Table 13. They are drawn from only 8 pairs of students. They show no significant superiority for the experimental group; indeed, the data for need 4 indicate a slight superiority for the control group, although so small that it might arise in 8 cases out of 10 from chance, even with a large number of cases. Nevertheless, the items appear to be representative and relevant, and the matter requires further inquiry.

The items involved are, for need 4, 2 and 5; for need 6, item 6. These items read:

2. If milk were adulterated with water, the effect could be most certainly detected by observing:
 1. The hydrolysis
 2. The Brownian movement
 3. The pH
 4. The freezing point rise
 5. The percentage of water in the milk
5. Homogenized milk stays homogenized because:
 1. Small droplets rise through a liquid more slowly than large ones of the same. [sic]
 2. Fat forms a lyophillic dispersion in water.
 3. The fat particles are stabilized by protein constituents of milk.
 4. Lactose exhibits a considerable detergent action in milk.
 5. Particles which lower the surface tension at an oil-water interface tend to be concentrated there.
6. Ice cream would probably not become sandy if:
 1. Freezing a solution did not force the solute from it.
 2. The solubility of lactose decreased with temperature decrease.
 3. Lactose were much more soluble than it is.
 4. A protective colloid were added to the ice-cream mix.
 5. The ice-cream mix were not very viscous when it is frozen.

The pattern of responses as shown by examination of the eight papers handed in by each paired member of the two groups, is given in Table 14.

Thus, the control group, among its eight students, scores one more correct response on items measuring need 4 than the experimental group. It is slightly superior on (2,4), which is both a fairly familiar fact which might be learned outside the course, and a relatively simple cryometric application which might be inferred from a traditional course. It is most superior,

TABLE 14

NUMBER OF STUDENTS IN EXPERIMENTAL AND CONTROL GROUPS
MAKING EACH RESPONSE ON ITEMS OF EXAMINATION F
MEASURING ABILITY TO APPLY CHEMISTRY TO
DAIRY PROBLEMS

Item	Response	No. Choosing - Experimental Group	No. Choosing - Control Group
1	1	1	2
2	2	1	0
2	3	1	3
2	4*	7	8
2	5	4	6
2	1*	3	6
5	2	3	2
5	3*	2	1
5	4	1	1
5	5*	2	0
6	1*	2	1
6	2	2	3
6	3*	2	2
6	4*	4	2
6	5	0	1

*Correct response.

on (5,1) which is also a rather obvious response which, perhaps, need not be specifically learned. Response (5,5); which is an application of colloid chemistry studied only by the experimental groups, is not successfully passed by any member of the control group, but is only passed successfully by two of the eight members of the experimental group.

Responses (5,2) and (2,2) are the only erroneous responses made by more experimental group members than control group members, and those by only one more student. Response (5,4) is chosen by one student each in both groups; the remainder of the distractors are chosen slightly more frequently by control group than experimental group members. None of these differences is sufficiently great to justify interpretation.

There is no response, correct or incorrect, on item 6 in which the control group demonstrates superiority to the experimental group, and only one, (6,3) on which it does equally well. The total differences, however, are not sufficient to be regarded as statistically significant.

On need 7, the application of chemistry to the problem of pest control, more favorable results are obtained. This need is measured by a considerable battery of items on both examinations E and F, which provides more opportunity to demonstrate differences, and differences are obtained. On examination E, with 14 students, a t-ratio of 3.657 is obtained; only 3.012 is required for significance at Fisher's 1 per cent level. On examination F, with 8 students and 6 items rather than 14, a t-ratio of 2.09 is obtained. This is not statistically significant even at the 5 per cent level until 20 degrees of freedom are obtained; it seems reasonable, however, to attribute the decline to the decreased number of items and students which restrict the opportunity to demonstrate differences, and to assume that the superiority of the experimental group demonstrated by Examination E is real.

For all the needs in subarea 2, which are related to the cultivation of soils, Examination E shows statistically significant superiority of the experimental group. For all of these except need 1, "To control soil texture for most effective plant culture," the t-ratios are greater than the 3.012 needed for significance at the 1 per cent level; for this the ratio of 2.232 is greater than the 2.160 needed for significance at the 5 per cent level.

Particularly striking is the very large critical ratio obtained for need 5 with a single item. In order to show how this came about, the item will be reproduced, with a table showing the number of students in each group choosing each response.

11. Due to overly intensive cultivation, much of the organic matter contained in a field has been oxidized, and its nitrogen liberated and washed away to a large extent. In order to remedy this defect, the farmer plows green cornstalks into the field. One would expect that:

1. The organic matter of the cornstalks would be incorporated into the soil through decay.
2. The nitrogen content of the field would increase sharply.
3. The nitrogen content of the field would decrease sharply.
4. The rate of evolution of CO_2 from the field would increase.
5. The pH of the soil would rise.

As shown in Table 15, the crucial factor appears to be the experimental group's awareness that the bacteria which lead to the decay of organic substances consume large quantities of nitrogen, and that improperly rotted mulches, instead of supplying

TABLE 15

NUMBER OF STUDENTS^a IN EXPERIMENTAL AND CONTROL GROUPS
MAKING EACH RESPONSE ON ITEM^b OF EXAMINATION E
MEASURING NEED FIVE

Response	No. Choosing - Experimental Group	No. Choosing - Control Group
1 ^c	14	12
2 ^c	1	7
3 ^c	11	1
4 ^c	9	5
5 ^c	5	1

^aOf a total of 14.

^bItem 11.

^cCorrect response.

nitrogen to the soil--as might be supposed by a person who loosely regarded them as a fertilizer--remove it. This fact could hardly be inferred from theoretical chemistry alone, and specific instruction with reference to this need undoubtedly accounts for the superiority of the experimental group. So far as the total superiority of the experimental group on examination E is concerned, it is noteworthy that the items on examination E are nearly all of a more concrete sort than those on examination C; knowledge of brief specific facts is tested in items 1 to 3, and 5; syntheses of knowledge involved in items 4, and 6 to 11, are closely related to agriculture as it is practised; the matching set in Part Three is perfectly concrete; and the situation to which principles are applied in Part Two have an agricultural reality not to be found among the items of examination D.

Examination F provides little data of value in judging the success of the course in helping students to apply chemistry to problems of soil cultivation. The only need in this subarea which is measured by the examination is need 4. The results indicate superiority for the experimental group, but not to a significant degree. Since the critical ratio obtained for this need on examination E is significant beyond controversy, and since only a few days elapsed between the administration of examination E and examination F due to the sudden truncation of both courses, it seems most unlikely that the superiority shown by examination E is spurious. Instead, one may conclude that the smaller number

of items was insufficient to demonstrate significant differences with only 8 pairs of students.

The critical ratio obtained by comparing experimental and control group scores on all items on examination F measuring needs in area 5 is 2.59. For significance at the 5 per cent level with 7 degrees of freedom a ratio of 2.36 is required. It may justly be claimed, then, that the experimental group is superior to the control group when the ability to apply chemistry to problems of vocational agriculture is considered as a whole, although this examination does not demonstrate such superiority to a significant degree for individual needs in the area.

The data cited above appear to justify the following conclusions:

The ability to meet needs within the dairy area has been so poorly evaluated that it is difficult to make any statements about the success of the course in this area with certainty.--Examination D was administered only to the experimental group, and all but 2 items on it measured either need 4 or need 6. Only items measuring these 2 needs contained correct responses which were chosen by more than half the students taking the examination, while only items measuring needs 2 and 4 contained correct responses which were chosen by fewer than one-fourth of the students. Complexity, abstraction, and obscurity of content appeared to be much more important than subject matter in determining which responses would fall into these two classes.

There is virtually no comparative data on needs within the dairy subarea. What little there is, derived from 3 items on examination F measuring needs 4 and 6, shows a very slight superiority for the control group on the former and a larger, but still not significant superiority for the experimental group on the latter.

Students of the experimental group show a superiority significant below the 1 per cent level to the control group in their ability to apply chemistry to pest control, as measured by examination E.--On examination F, with 8 pairs involved, the superiority observed is not quite sufficient to be significant at the 5 per cent level.

Students in the experimental group show statistically significant superiorities to students in the control group on all needs within the soils subarea, as measured by examination E.--All

but one of these superiorities is below the 1 per cent level. Only 1 need in this subarea is measured by examination F; results show statistically insignificant superiority for the experimental group.

CHAPTER XI

APPRAISAL OF SUCCESS IN MEETING NEEDS IN AREAS SIX AND SEVEN

Brief Characterization of Areas Six and Seven

Area 6 is defined as the need to make effective use of leisure time. Specific needs within it would include the need to conduct any particular recreational process to which the application of chemistry is useful. Perhaps the most chemical of hobbies commonly practiced in our culture is photography. Gardening, another popular form of recreation in which chemical knowledge is useful, is hardly a suitable avocation for people whose vocation is agriculture, and, in any case, the chemistry involved in growing things for pleasure is the same as that in growing them for profit; no new content could have been introduced by including the need to enjoy gardening as a possible problem for students to consider in area 6. Cookery, another hobby quite common among urban men, is almost wholly a feminine function in the rural southwest; furthermore, although completely a chemical process, it so largely involves organic rather than inorganic reactions as to be inappropriate here for the same reasons that areas 1 and 2 were deleted. Photography was therefore the only recreational activity studied intensively in this area.

Area 7 is defined as the need to defend oneself against hostile environmental forces. This area, in retrospect, does not appear to be valid in the same way that the remaining 8 in the original classification of needs are; it is negative, and might quite easily be subsumed under positive aspects of other areas. Even defending oneself against an atom bomb may be looked at as a part of the need to remain in as good health as possible, or for that matter, of the need to present an attractive personal appearance, or to use leisure time effectively. During wartime, however, one is acutely conscious of hostile forces; they disrupt all aspects of life and dominate the goals of social planning. An area seemed to be needed which would represent the needs

created by the special conditions of warfare, and it was for this purpose that area 7 was intended.

Unfortunately, consideration of problems in these two areas was very sharply truncated by the early termination of the academic year due to the attempt to enable students to complete their courses before being drafted. The attempt was, moreover, largely futile. Most of the students in both groups were members of the Enlisted Reserve Corps of the United States Army, and were called from school a fortnight before the time which the college had attempted to set for the new end of the school year. Less time than desired could therefore be devoted to these areas, and no evaluation instrument designed to measure the ability to use chemistry to solve problems within them could be designed in time. These areas were measured only by a few items on examination F.

Relation of Items to Areas, and Evaluational Data

Only one need--the need to apply chemistry to the enjoyment of photography--was evaluated in area 6. In area 7, while items could be classified according to the specific military technic against which they were designed to teach students to defend themselves, such a classification would merely serve to further divide an already inadequate group of items, and would be of purely technical interest. No attempt will be made here, therefore, to relate items measuring needs in area 7 to specific needs. All the items relate to the chemicals of warfare--toxic gases and explosives--and their behaviour. All the items are taken from examination F. Items measuring in area 6 include 15 and 16. Items measuring in area 7 include 14, 17, 18, 134, 137 and 139. Results obtained are presented in Table 16.

TABLE 16

RESULTS OBTAINED FROM EXAMINATION F IN MEASURING
OBJECTIVES WITHIN AREAS SIX AND SEVEN

Area	M_x	M_c	σ_{diff}	t
6	1.250	1.250	0.000	0.000
7	5.000	3.625	1.24	1.11

Obviously, there is nothing here worth interpreting. The superiority of the experimental group on area 7 is too small to be significant, although it is perhaps as large as one can hope to get with 8 pairs of students and 6 items. On area 6 there is no difference, and it is hard to rationalize a difference of nothing at all on any basis. It is of interest, however, to examine the distribution of responses within items 15 and 16 to see if the identity is complete, or the results of compensating differences. The items and the distribution of response on them are reproduced below:

15. Sodium thiosulfate is used by photographers chiefly to:
 1. Prepare a sensitized film to receive the photograph.
 2. Reduce the exposed silver bromide particles and thus develop the picture.
 3. Dissolve the undeveloped portions of the emulsion to prevent subsequent "fading."
 4. Prevent the gelatin of the film from being softened in the fixing bath.
 5. Convert the silver bromide particles in the film to metallic silver.
16. A photographic negative comes from the developing bath much too dark to be satisfactory. This might have resulted from:
 1. Allowing too little light to reach the film when the picture was taken.
 2. Using too warm a solution of developer.
 3. Leaving the film in the developer too long.
 4. Using a developing solution with an insufficient reducing potential.
 5. Using too large a diaphragm opening and too slow a shutter speed.

As will be seen in Table 17, the equality between the two groups exists within each item as well as for the 2 items as a whole, although it is true that within item 16 there is a difference between the groups with respect to individual correct responses. The same number of correct responses, however, is made by each group on both items. The most interesting differences observable are the greater immunity of the control group to the distractors of item 15 and the freedom of the experimental group from the misconception that the lightness of a negative is directly proportional to the intensity of illumination to which the film is exposed--surely the most basic misconception possible of the photographic process.

Interpretations

Data available on the performance of experimental and con-

trol groups on areas 6 and 7 are inadequate.

There is no basis for inferring any difference between the two groups with reference to the ability to apply chemistry to the problems of photography. The mean number of responses correctly scored by each student is one and one-fourth out of a possible four, which is very low in both cases.

There is an indication of superiority for the experimental group in the ability to apply chemistry to problems of civil defense, but it is not statistically significant.

TABLE 17

NUMBER OF STUDENTS^a IN EXPERIMENTAL AND CONTROL GROUPS
MAKING EACH RESPONSE ON ITEMS OF EXAMINATION F
MEASURING AREA SIX

Item	Response	No. Choosing - Experimental Group	No. Choosing - Control Group
15	1	2	0
15	2 ^b	3	1
15	3 ^b	3	3
15	4	2	1
15	5	2	0
16	1	2	6
16	2 ^b	1	1
16	3 ^b	2	4
16	4 ^b	2	3
16	5 ^b	4	2

^aOf a total of 8.

^bCorrect response.

CHAPTER XII

APPRAISAL OF SUCCESS IN MEETING

NEEDS IN AREAS EIGHT AND NINE

Brief Characterization of Areas Eight and Nine

In each of the areas of need discussed in the foregoing chapters, the needs concerned were used as a basis for the determination of course content. It was expected that the subject matter of the course, which had been chosen because of its relation to the pattern of needs described in Chapter IV, would be useful in helping students to meet those needs. The degree to which this expectation was fulfilled has been appraised in the preceeding four chapters.

The objectives of areas 8 and 9, however, are largely unrelated to course content. Learning experiences which were expected to contribute to attainment of these objectives were to be derived primarily from the method of the course--that is, from its manner of organization and the nature of the demands which it made upon students. It has already been stated, in Chapters V and VI, that the technics of instruction in the experimental course resembled those of a conventional course in that lectures, discussions, published materials, and occasional visual aids were used. There was, however, a considerable difference in the role of student in the experimental program and in the control program. This difference in roles may be summarized as follows:

Students in the experimental course influenced the course content by the problems which they selected as the basis of study.--Not only were they relatively free to select for themselves topics of interest to them, but their choices influenced the instructor's class discussions, and largely determined what laboratory exercises would be performed and what reference materials made available. Proposed topics which attracted little interest were either omitted from the discussions or treated very briefly. Students were thus aware at all times of their influence on the curriculum to be provided for them. In the control group,

no provision was made for the expression of student choice with respect to the content to be included, although the instructor sought to use his soundest judgment in treating the traditional subject matter of freshman chemistry in a way comprehensible to the students.

Students in the experimental course influenced course policy through their elected representatives.--While this group initiated little action, problems of an administrative nature, such as difficulty in obtaining materials, inadequacies in materials provided, and any discontent with or suggestions for the modification of course procedure, were promptly brought to the attention of the instructor and a decision as to the most satisfactory course of action made. No formal provision of any kind for continuous consultation of students existed in the control group.

Students in the experimental group were not given a textbook or specific page assignments.--Instead they were provided with lists of specific references for their guidance. The amount of work which they chose to do, and the particular readings to which they gave attention were, with one or two exceptions, their own choice. Students in the control group were provided with a single text, in which daily assignments were made.

Students in the experimental group were required to write original reports dealing with the application of chemistry to each of the problems they had chosen for intensive study.--They were expected to synthesize learning from various sources into a meaningful statement dealing with the issues which they regarded as important. No such requirement was made of the control group.

These differences in procedure were planned specifically to contribute to the student's ability to meet needs in areas 8 and 9. These needs will be recapitulated here from Chapter IV:

Area 8. The student needs to participate effectively in the processes of democratic society. The student needs:

1. To be able to use libraries and other sources of public information effectively.
2. To participate in the decisions affecting the policies of his group.
3. To distinguish between reliable and unreliable authorities and sources.
4. To distinguish semantically between meaningful and meaningless language.
5. To act politically with understanding of the effect of

technological advance on possible standards of living, and on the validity of current social and economic concepts.

Area 9. The student needs to develop into an adult: a mature, self-reliant personality. The student needs:

1. To be able to organize his work with a minimum of assistance from others, except experts called in to settle questions beyond his knowledge.
2. To complete undertaken responsibilities reliably.
3. To understand and accept his own personality, while seeking to improve its weaker traits.
4. To find his chief motivation in his personal goals, rather than extrinsically.
5. To demonstrate, by co-operation and tolerance, respect for the personalities of others.

Other factors than the course procedure were utilized in helping students meet certain of these needs. Specific instruction was provided to assist students in meeting needs 4 and 5 of area 8, while the instructor sought to provide counseling for those students who appeared to be having noticeable difficulty in meeting need 3 of area 9. For the most part, however, the course would contribute to growth toward these objectives through its method.

Evaluation and Conclusions

Although the behaviours in terms of which needs in areas 8 and 9 are defined are as specific as those for any of the other areas, it seems obvious that the same methods of evaluation cannot be applied here. All the needs of area 8, except need 2, are of such a nature that the achievement of them could be measured by paper and pencil tests. Such tests, however, would have been almost inexplicable to the control group, whose members would not have conceived them to measure objectives appropriate to the chemistry course; they were not deemed desirable by the departmental administration, and were not used. Little, in the writer's opinion, could be accomplished by trying to measure achievement of the needs of area 9 by paper and pencil tests, though objective technics of observation might have been worked out which would have yielded reliable quantitative measurements. This did not appear to be practical to the writer, as it would have been similarly difficult to apply to the control group under the existing conditions. Furthermore, the behaviours of area 9 would be completely meaningless if exhibited under circumstances in

which they were elicited in response to a test situation used in assigning a grade, since their meaning derives from the fact that they arise from self-direction.

Two sources of information as to the ability of the course to contribute to needs in areas 8 and 9 are available: the anonymous comments about the course collected from 33 students, and the reports written by the students in connection with their problem topics, samples of which have been preserved. The comments are relatively brief, and are all reproduced in Appendix B. They provide a basis for inference concerning other matters of interest besides the ability of the course to help students become mature, self-directing persons and effective participants in the democratic process; notably, they shed light on the degree to which the technics and objectives of the course were appropriate to the students to whom it was offered. Since, however, this appropriateness was a major factor in determining the emotionalized attitude which the students came to have toward the course, it in turn affected their disposition to accept or reject its objectives, especially those which were relatively unfamiliar to students as a part of the concern of the school. Areas 8 and 9 clearly fall in this class, and it would therefore seem legitimate to discuss the student comments on the course fully in this chapter, even where those comments deal with questions of technic; one's preference for being taught in one way rather than another often reflects one's willingness to accept responsibility for organizing work and formulating policy.

The statements, as given in Appendix B, have been classified on a five-point scale of feeling tone. The classification is subjective, and may be unreliable. The following positions on the scale are recognized: (1) totally favorable, (2) predominantly favorable, (3) ambivalent, (4) predominantly unfavorable, and (5) totally unfavorable. No attempt has been made to provide in the classification for variations in feeling intensity; only the total complexion of the statement is considered. Totally favorable, for example, means completely, not passionately, favorable. It must also be indicated that the statements vary considerably in length, and that some are probably totally favorable or unfavorable rather than partially so merely because fewer issues are considered by the student. Although all the statements are included in Appendix B, examples of each are presented below for

easier reference in the course of the discussion:

1. Totally favorable

At the beginning of this course I thought it was going to be very hard and dull, but after the course had gotten under way, I decided that it was the most interesting course that I had ever taken. The reason that I liked the course so well was due to the fact that it is more practical. I believe that all students in the school of agriculture that take 134 Chemistry should be taught this way because it is more practical. Although I did not do so well on the reports, I thought that they were very interesting because you can learn more things that will help you later in life. I do not know of any part that is wrong with this course.

2. Predominantly favorable

We, being an agriculture group of students, were taught along on something that would be practical and of value to us in everyday life. This course was not especially designed for teaching one how to do formula writing, but rather to make us familiar with chemical terms and to teach us the content of an element or compound. Then too, we tested each thing to find its properties, to see the chemical change or reaction, and to be able to tell whether it would be profitable as something for common use or not. In many instances in this course we have been allowed to think something out ourselves and have been required to search for our own reading material. This was on the whole very good training.

There is only one objection I would have to this course. That is this, that the person taking it should first have an excellent background or fundamentals for chemistry so he can easily understand what is taught.

3. Ambivalent

In this course we have learned more how to apply chemistry to our daily needs. Such a course is very practical. However, I was unable to grasp some of the basic fundamentals of chemistry which are dwelt upon more extensively in other chemistry courses. The course, as a whole, has been very profitable to me.

It is true that we must learn how to apply the knowledge which we obtain. But this cannot be done until we have a thorough conception of the rudiments of chemistry.

4. Predominantly unfavorable

This course does not dwell on one topic long enough for a student to learn enough about that topic. Your lectures are too hard to understand because you use too many big words that we do not understand the meaning of. I have enjoyed the lab work and the class because it is interesting to work out these experiments, and I think it has achieved the result desired fairly well.

5. Totally unfavorable

Without specific reading assignments I feel that the average student will do very little reading. There are a few weak points in the lecture. The material is usually well covered, but it is virtually impossible to take a reasonable set of notes. Due to the fact that there is no specific assignments or reading material the students lack in the basic facts and rules of chemistry.

The distribution of statements in Appendix B along this five-point scale is given in Table 18.

TABLE 18

CLASSIFICATION OF ATTITUDES OF ANONYMOUS
STUDENT COMMENTATORS

Feeling Tone	Comments	Total Number Commentators
Totally Favorable	5, 10, 13, 17, 24	5
Predominantly Favorable .	1, 3, 6, 9, 14, 20, 22, 23, 27, 29, 30	11
Ambivalent	2, 7	2
Predominantly Unfavorable	4, 8, 11, 15, 18, 21, 26, 31, 32, 33	10
Totally Unfavorable . . .	12, 16, 19, 25, 28	5

Clearly, a distinction exists between the adaptation of a course to student need, as here defined, and catering to the immediate desires of all students. The comments are almost evenly balanced between favorable and unfavorable; there is one more "predominantly favorable" than "predominantly unfavorable" comment. Evidently the experimental course has not played the role of a revision in response to popular demand.

Analysis of statements occurring in the comments of more than one student makes the data much more meaningful. These statements will be listed in order of descending frequency. Of course, they are not expressed in identical words by several students, but the writer believes that they are clearly embodied in the comments and that interpretation has been avoided. This data will be found in Table 19 on the following page.

What are the implications of these data? Thirty-nine per cent of the comments include a statement that the course is practical; that it is closely related in most or all of its parts to the life which the student expects to live. This statement is made more frequently than any other. It was made by 3 of the 10 students whose attitude toward the course is predominantly unfavorable, and 1 of the 2 classed as ambivalent. This seems to

TABLE 19

STATEMENTS INCLUDED IN COMMENTS OF ANONYMOUS
STUDENT COMMENTATORS

Statement and Source Comment	Total Number Comments Making Same Statement
Course is Highly Practical 1, 2, 3, 6, 7, 8, 10, 13, 18, 22, 29, 30, 32. .	13
Course Lacks "Fundamentals"; Previous Knowledge of Chemistry Required to Understand it 2, 3, 4, 7, 12, 22, 27, 28, 29, 31, 32.	11
Course Does Not Teach You to Understand Equations and Formulae 1, 7, 16, 25, 27, 31, 32	7
Student Feels Need of Textbook to "Fall Back On" 8, 12, 16, 21, 30, 33	6
The Language of the Instructor Is Too Complicated to be Understood 11, 20, 29, 33	4
Student Feels Unprepared to Take Further Chemistry 28, 32, 33	3
More Visual Aids or Materials Needed 24, 26, 20	3
Poor Discipline in Class 9, 19	2
Course Devotes Insufficient Time to Each Topic 1, 11	2
Course Allows Students to Reason Things Out for Themselves 3, 5	2

indicate that a large proportion of the class regards the objectives of the class as valid, although some of the students who so regard them feel that defects in methodology are sufficiently serious to prevent their giving a favorable report on the course as a whole. Six of the 11 students whose attitude toward the course is predominantly favorable regard it as practical, and 2 of the 5 whose attitude is totally favorable make the same statement. Since both these are considerably larger proportions of the total number reporting the attitude than is the case for the "predominantly unfavorable" students, it seems likely that the needs chosen as a basis for selection of content are regarded as valid by many of the students, and that this validity is a major factor

in supporting the favorable attitude which certain of the students feel.

If this is true, one may place greater confidence in any examination results which indicate that students in the experimental group are able to use chemistry to solve problems of importance to them. Such examination results can indicate only that students are able to do so, not that they are disposed to do so. Any evidence which tends to establish further that students regard the problems as important, and believe that the course has been of practical value in helping to solve them, makes more plausible the inference that the behaviours exhibited on the examination will also be practiced in real situations.

The implications for behaviour with reference to the objectives of areas 8 and 9, are much more unpleasant. Eighteen per cent of the comments complain of the absence of a textbook. No textbook could, of course, have been supplied for a course designed to meet the needs of students at the college level; no appropriate book exists. Only by yielding much of the "practicality" of the course could a text have been used. Yet 2 of the 6 students who wished a text supplied also described the course as practical, although only 1 of the 6 had a "predominantly favorable" attitude toward the course--he being 1 of the 2 who regarded it as practical. The other 5 had either predominantly or totally unfavorable attitudes toward the course.

This indicates that the need "To be able to organize his work with a minimum of assistance from others" (area 9, need 1) was rejected at the level of behaviour which the course required, by a considerable minority of the students, who regarded such an obligation as a threat. These students would be unlikely to derive added maturity from the experiences of the course, and, indeed, might be so disturbed by it as to reject the course experience totally as a behavioural influence. Their achievement of objectives 1 and 3 of area 8, "To be able to use libraries and other sources of public information effectively," and "To distinguish between reliable and unreliable authorities and sources," is also improbable; the behaviours in terms of which these objectives were defined were probably inappropriate to these students. As opposed to these students, only 2, 1 of whom had a "predominantly favorable" attitude toward the course, and the other a "totally favorable" attitude, expressed appreciation that

the course enabled them to think through their own problems.

Interesting, also, is the complaint of 21 per cent of the commentators that the course did not teach them to use equations and formulae. Three of the 7 students making this statement also regarded the course as practical. Yet, familiarity with chemical nomenclature is of very little practical value to persons working in agriculture. Why should any student who prized the course for its practicality, complain that this burdensome objective had been eliminated? This objection also seemed highly prejudicial; only 2 of the 7 students reporting it had a "predominantly favorable" attitude toward the course.

This, taken with the context of the comments in which the statements occurred, seems to arise from a feeling that a chemistry course which does not deal with equations and formulae is not, somehow, authentic. There is, of course, a legitimate basis for complaint for those students who felt their understanding of the course hampered by lack of instruction in the language. Most of those wishing more emphasis on equations and formulae, however, seemed to be motivated by the same kind of anxiety which causes collectors of fine antique furniture to wear themselves away attempting to distinguish the real from the spurious Duncan Phyfe, and to welcome such defects as prove the piece genuine. Such an attitude is in direct contradiction to the functional philosophy of the course, and subtly repudiates objective 4 of area 9, for students holding it cannot find their ". . . chief motivation in [their] personal goals, rather than extrinsically."

Two students, 1 of whom had a "predominantly favorable" and 1 a "totally unfavorable" attitude toward the course, complain of a matter which they apparently regard as disciplinary--that some students occasionally sleep in class. In this matter there is room for controversy, but the writer believes that the philosophy of the course would have forbidden him to interfere in student behaviours which did not infringe the rights of others, and that students who complain of other students inattention are far from achieving objective 5 of area 9, "To demonstrate by co-operation and tolerance, respect for the personalities of others." A student who believes that a brief slumber meets his needs more fully than a class discussion may be right or he may be wrong, but is surely in a better position to judge than the teacher; nor can such behaviour be considered discourteous unless the teacher

is more identified with his role than with his students.

Other aspects of the student comments which shed more light on deficiencies of technic than on the achievement of objectives within areas 8 and 9 will be discussed in a later chapter. The most important implication of the data cited above with reference to the effectiveness of the course in these two areas is, in the writer's opinion, that the behaviours chosen to denote effective participation in democratic processes and mature self-reliance are inappropriate to many of the students. Probably the criteria of growth toward democracy and maturity should be revised so as to permit recognition of smaller steps in these directions and permit growth to be evinced by behaviours which do not impose heavy intellectual responsibilities on the students. The behaviours which the course measured had not been encouraged by their previous experience and did not appeal to them; indeed, they were threatened by the need to develop such behaviours. The group of students to whom this applies is probably not a majority, but is certainly a large minority. One may infer that this group was not helped toward more mature and democratic actions; the most hopeful conclusion that can be drawn is that students who felt most threatened by the greater responsibility for self-direction imposed by the experimental procedures are clearly being made aware that self-direction is an alternative available to human beings. This, however, is not enough. In 1946, God knows, a person who does not wish to behave tolerantly, to respect the personality of others, or to assume responsibility for his own actions, has ample opportunity to join with powerful forces to eliminate tolerance, respect, and responsibility from his environment.

Since the reports written by students on problem topics are the major responsibility undertaken by them, and since they afforded an opportunity for almost complete self-direction, examination of them should yield information as to the manner in which certain individuals, at least, achieved or failed to achieve the objectives of area 9. It is not practical to reproduce these reports in full in this document, since they are a relatively inefficient source of information. They may, however, be described in relation to several general classes into which they may be grouped, and examples taken from certain of them analyzed. Five general classes representing 4 levels of achievement within the

area may be cited, as follows:

1. Scholarly, well-organized applications of chemistry to problems conceived at a level close to the student's experience.
2. Scholarly, well-organized essays on the chemistry involved in an aspect of agriculture, or other field, theoretically conceived.
3. Loosely handled original essay on topic with little application of chemical principle and little documentation.
4. a. Direct paraphrase of material from one or two published sources.
b. Semi-illiterate original essay.

As an example of the first type, one may take the paper entitled "The Protection of Plants by the Aid of Insecticides and Fungicides in Oklahoma" by student S.S. This is an eighteen-page monograph citing 8 references to books and agricultural bulletins. After a three-page statement in which general problems of technic in preparation and application of insecticides and fungicides are discussed, the following paragraph occurs:

In the following paragraphs I am going to discuss some of the common fungicides and insecticides employed in Oklahoma. I am going to consider their chemical properties, action upon fungi or insects or both, and effects upon the plant.

The remainder of the paper is devoted to this task, which is done completely, and with profound attention to the chemistry involved in the action of all agents discussed. Only those agents actually available and in use in Oklahoma are considered, however. There is no attempt to extend discussion beyond the point at which it is actually applicable to the Oklahoma farm situation.

The second type is represented by a paper by student D.S., who wrote on topic 3 of the soils subarea, "How may essential constituents of the soil be replaced. . . .?" This is a five-page essay, citing 2 references; 1 to Soils and Men, and 1 to a published article. The author discusses the major soil constituents and the cyclical processes by which they become available and are spent. Nitrogen fixation is discussed; the Haber process is described. The chief chemical substances used in fertilizers are discussed in paragraphs like the following:

The principal phosphatic fertilizer materials used in the United States are superphosphate, treble superphosphate, and ammonium phosphate. Superphosphate is phosphate rock treated with sulfuric acid to make it soluble. The phosphate makes a rather rapid return to a insoluble form in the soil but it is much more finely divided than if it had not been rendered

soluble. Triple superphosphate is made by treating phosphate rock with phosphoric acid. It is a richer source of phosphorous than superphosphate and contains no gypsum. Bonemeal is a good source of phosphorous and also of nitrogen.

The paper is substantially accurate throughout, but at no point does the author abandon his substantially theoretical viewpoint.

Excerpts from several papers will be quoted to illustrate the kind of material classified under "3" above. From a three-page undocumented report on "Undesirable Odors and Flavors in Milk" by student M.F. we take the following paragraph:

Feed has a very distinct effect on milk. Feed not only affects the flavor and odor of milk but also affects the color. Omitting the breed, the amount of pigment in milk depends on the amount in the feed. Other products not normally found in milk are volatile oils. These volatile oils are found in onions, garlic, turnips, and rape. Of course there are many other seasonal weeds and plants that may affect the flavor and odor. These volatile oils are not natural oil but are dissolved in the fat or serum.

In a paper of similar length, dealing with the topic, "What Are the Chief Constituents of Milk, and How Are They Stabilized?" student G.M. writes:

Next we look at the individuality of the cow. Within a herd of cows of a single breed, there may be considerable variation in composition of milk between individuals, even though they all have the same care feed and environment. These differences are due many things but probably the most important is inheritance.

Student E.C., a stylist fully as fascinating as Leonard Ross's Hyman Kaplan writes in a paper on "How Can Chemistry Help Me to Control Insects. . . .?"

In the United States alone the cotton boll weevil has caused over \$200,000,000. dollars worth of damage. The boll-weevil is spread over the entire cotton belt and the controlling of the insect is a vital problem to our cotton industry. It is possible to control this pest effectively without damaging the plant. The approved method of direct control is to dust cotton plants with calcium arsenate. The parson is applied from 4 to 6 pounds per acre. Three applications are necessary to the best results. The same control is used for combating with the cotton leaf worm.

Termite may be controlled by a simple mixture of sodium orsenate, coal-tar creasote, and kerosine oil. You will have to strain mixture before using it. Also carbon disulfide emulsion is good.

The use of poisons as insecticides is regarded as dangerous to human life, but the amount on the fruit is not sufficient to be harmful to consumer. The excess residue is usually removed from the plant anyway so there is very rarely

an harmful effects to the consumer. The same answer usually applied to animals. However, there is a little danger of poisoning poultry by letting them run in sprayed orchards.

Fumigation is only proctised indors as it would be a waste to do it out side.

In the first two papers quoted, there is barely any reference to chemistry. The third, while superficial, is, despite its Artemus Ward spelling, much better, since there is clear application to real farm problems. It has been placed in class 3, however, because it is almost completely devoid of theoretical backing, and is not therefore really a study in chemistry at all.

Class 4a is well represented by a paper on water purification by student E.S., a friendly, almost inarticulate, certainly un-literary fraternity and campus leader. He writes:

The physical characteristic includes turbidity, color, taste, odor, and temperature. These characteristics in themselves have little effect on the health of persons drinking the water. People naturally prefer water which is clear, colorless, odorless, cool, sparkling, and pleasant-tasting. They drink more of it, and thus their health is benefited. No one likes water that is turbid, colored, unpleasant-tasting, warm, dull, or of foul-odor, although it may contain no germs and be quite safe.

Student D.K. writes a four-page paper without documentation on the topic, "How Can Chemistry Help Me in Choosing a Fuel System for Heating a Home." It can only be classed as 4b as the following excerpts show:

Isn't it nice to have a warm comfortable home to live in. It is very necessary to heat a house because it is one of the necessity's of life and for the health that you have. A house can very easily be overheated by a big fire. This can be prevented by having a thermometer in your home for the regulation of heat. Most people always have there home hotter than necessary and when go outside they catch coal.

Another very important fuel is wood. People who has a creek or river on there farm comes in very handy. They wont have to worry about the cost for fuel. On the modern cities its use is almost entirely limited to the fireplace and to haven kindling to start a fire.

One of the most convenient fuels we have today is electricity. We furnish homes with electric lights, the electric refrigerator, stoves, and many other electric appliances we can use with electricity.

There is a break to farmers who has the Rural Electrification but mostly in the cities where is most popular. There are also electric washmachines we use instead of the scrub board which we labor over.

Another kind of fuel which is becoming very popular, we call steam. for the winter it may be installed at any point

of which coal may be handled, and where is an adequate supply of densing water; it has a third advantage of being flexible, that is, its output may be reduced for any period of time, for three or four hours for example.

In all fairness it should be pointed out that the misconceptions in this paper are largely verbal, and that, despite its macabre misuse of language which is worthy of one of James Thurber's most inscrutable cooks, there may well be a fairly good underlying grasp of the function of a heating system in the home. This is an excellent example, however, of the failure of the course to define its objectives in terms of behaviours also appropriate to the relatively non-verbal student.

Papers on problem topics are nearly devoid of statements indicating how students felt about the learnings offered by the course, since they are expository factual accounts at such a level as the student is capable of constructing. They do not usually include opinions or evaluations, and each is written on a topic selected by the student himself so that there is no conscious rebellion against the task. The papers written in review of Bernal's The Social Function of Science provide more scope for student opinion, and a better controlled opportunity to estimate the appropriateness of scholarly publications to the reading comprehension of the student. The content of the book also is basic to the contribution of a science course to the ability of students to participate effectively in the democratic process. Examples from these reports are useful, hence, in appraising the attainment of objectives in area 8. Unfortunately, very few of these papers exist, since they were among the final obligations of the course which few students remained to discharge.

None of the samples of this paper which have been preserved are of excellent quality. The worst of them are flowery, derivative, and tend to combine tributes to the glory of science with attempted paraphrase of Bernal's profound criticism of its social role with disastrously inconsistent results. One is copied directly from the book. Another, while sharing the faults of the first, seems yet to result in good understanding of the necessity that science be integrated into the culture which it proposes to serve. Thus, student W.P. writes:

Nearly two hundred years ago, scientist knew very little about science. Science has been an important factor to education all down though the ages.

Science is used for the sake of knowledge of what comes in to existence and stays eternally and not what exists one

moment and then it perishes. In that way the knowledge of science can be used in the future.

There are two things which slows down the scientific research. One is the general atmosphere of sercecy in which the research is carried out, and the other is the research worker lacks the freedom to do as he likes.

It is really no use improving the knowledge that scientists have learned about other work if we do not at the same time see that the real understanding of science becomes a part of our common life in our times.

One might support that a book like The Social Function of Science would be inaccessible to students such as those in the experimental group by virtue of the sophistication of its concepts and the scholarly language and format. This does not appear to have been true. Certainly, a majority of the students were unable to write a satisfactory critique of the work. But this seems to have resulted from almost total unfamiliarity with the technics, or even the purposes, of intellectual criticism, which would doubtless have been regarded as presumptuous in most of the school situations previously encountered by them. This, of course, is further evidence that the objectives of area 9 were defined in terms of behaviours inappropriate to the students. Student M.F., a boy of mediocre ability but relatively free from false academic humility who appeared well adjusted to the course procedure writes:

I was surprised in finding that the author did not use too many scientific words and names. The book seemed to be very well suited to my reading ability.

To me the author seemed to be a little bit on the radical side in connection with science and war. . . . However the author did bring out some very good points on chemical warfare.

Student K.R., whose academic habits were even less scholarly than those of M.F., and whose self-esteem was even more buoyant, writes:

I enjoyed Bernal's book very much. It was not only enjoyable but educational to me, because of the way it was written and the things written about. . . . The most interesting and educational chapter of part one for me was the discussion of Science and War. It is an outline of war research today, sciences contribution to previous wars and science and arms. . . . The most outstanding chapter in the whole book was Science in the service of man. This chapter was an analysis of what science could do for man in the lines of food, clothing, housing, health, work, and play. This was the best chapter in my estimation because of its timeliness. . . .

I didn't have as much time to read this book as thoughtly as it should have been read, but when I came across a chapter that I enjoyed, I directed a little more time to the reading of it than other chapters less interesting to me.

But perhaps the most interesting of these papers is the one written by the same E.C. whose remarkable treatment of the insecticide problem is quoted extensively above. This paper is an astonishing paradox of comical linguistic ineptitude blended with exceptionally keen insight into the meaning of the book at the level of the student writer's experience. This delightful document is reproduced in its entirety:

The Social Function of Science

The following is an outline of Berneal book, "The Social Function of Science". Many of his opinions are altogether true and many of them are a bit exaggerated. But this is only my opinion against his. The following statements are concerning the parts of the book which I considered to be of the most importance and of more interest to me. In other words I agree with his opinion in these statements. However, as his book goes into so much detail for which I see no need for so many of the statements that he has written, I shall preceed to try to relate the emportant parts.

The industrial revolution brought the first great change in science. The new science gave forth the ideas for the newly rising industries. This science predominated over industry for the first time in history. Since the universities of that time were at a very low level, the men of science founded their own branches of higher learning. One of the first was founded by Franklin. Then later came the famous Royal Institute of London.

The necessity for science was now clearly understood. But still science was without the proper funds with which to carry on their work. The great industrialists used the work of science but paid little for it. It was not until the first World War that science really got underway.

The research of today is done mainly by the students at universitie who want to obtain higher degree of learning. Now a Ph. D. is a necessity for a man to become somebody in the world of science. But this areses into complication because when the man does the necessary research he usually the precedes to teach or go into some industrial position. This leaves us without the individual research work. He is the man that really has interest in his work because he is doing what he wants to do. The branches of research include that of chemical, engineering, medical, agriculture, etc. The funds for this research comes from various sources. Most of it from the government. All of these action arese into problems of the administration of the research.

The teaching of science is a great problem to our social world. Few children know the teachings of science until they are fourteen. The teaching of science in unversities gives a liberal education but each branch is given to you as if you were going to make that particular subject your life study. If science were only taught to you in a way in which the tech-inecialitie were done away with and more of the social side of that particular branch of science were given to you then it would seem to help you considerably more.

There is for too much secretecry on the part of the research worker in industry. This prevents the contact with fellow scientists who made the working on the same problem.

The research work is usually held under contract by and industrialist. Therefore, he may never know the final return of his labor. This causes him to be uninterested in the work which he is doing.

War always bring a rise in the production of science. But the researchers who are testing materials of war are entirely too wasteful. This gives a rise to economic problems as all the material used must not be wasted. During warfare we must conserve our present supply of materials. Science has a large job during a war as it has also got to solve the problem of synthetic materials as well as food materials. Science has made war a far more dreadful thing than it used to be. But it alone can be complimented for all of our new weapons of modern warfare.

The work of science has brought forth many theories. These are in many cases very confusing and it has been thought by many that it would have been thought by many that it would have been far better to stick to plain facts than to turn to theory. The further you proceed into the depths of science the more complex the situation seems to be.

All of the methods of teaching seemed to rise into further complications. Complex equipment was needed to explain even more complex facts. Both the complex equipment and complex theories are far too much for the average student.

Popular science is an important to us today. We learn the usefulness of all of the new discoveries. The magazines and movie shorts give to us, the average citizen, a clearer picture of the greatness of science. Books are always helpful. Some are much too complicated and cover only one particular subject. These kind of books are essential to the researcher but shouldn't be allowed to be read by the average John Doe's. It only somewhat mixes them up more on science. Science in general should become familiar to everyone. The citizens should actually in the minor work of science. When this can be done science will behold a high position in the social world.

Chemistry is closely allied to all of the other sciences. Much of our chemical processes are accomplished through tradition only. It seem that it is possible for us to accomplish our endpoint in many easier way but we're afraid to change our present way of doing things. Food is the main chemical problem of today. All of the processes of handling storing, and cooking food refers us to a chemical process. Chemistry has put out a lot of excellent drugs but many of them are not needed and do us more harm than good. The same is for cosmetics.

However chemistry does help us discover new and better materials to us. The new products are usually for better than the old ones. But again we run up against the problem of tradition. We don't want to change our present status because we seem to be uncertain of the results.

The ever old controversy between science and religion is still going on. It is still thought by many people that scientist is irreligious just because he stood for the clearly evident facts of science. This is because of the ignorance of the public to the knowledge of science.

The same holds true with the traditions of culture. A certain theory of olden times can now no longer stand today unless it has been a proven fact. You should always have an explanation for your belief as science either classifies

things as realities or just out of the question. But to get everyone to know science we must first do away with the dryness of the subject. But when we do accomplish the science will then regulate the social changes in the world.

Perhaps the most important conclusion which can be drawn from reading these reports is that the course depended too much on them. Clearly, a wide range of competence exists in the verbal application of chemical principles to the solution of problems. Nevertheless, few of the reports cited show much ability to "use libraries and other sources of public information effectively," "distinguish between reliable and unreliable authorities and sources," "distinguish semantically between meaningful and meaningless language," or "act politically with understanding of the effect of technological advance on possible standards of living and on the validity of current social and economic concepts." Nor do they demonstrate that their authors were "able to organize [their] work with a minimum of assistance from others. . . ." or that they "find [their] chief motivation in [their] personal goals rather than extrinsically," though some of them did all these things, and many did some of them.

If scholarly criteria are held in abeyance, however, the results appear somewhat more favorable. Many of the reports show a willingness of the student to write what he feels to be true or appropriate rather than what is expected of him, though others are apparently copied. The worst of the reports technically, however, often show a surprisingly strong relationship to the student's experience; perhaps because he lacks the ability to transcend it.

Evidently, then, a chemistry course can contribute to a student's need to participate more effectively in democratic processes, and to develop greater maturity and self-reliance. For many students, including most of these, however, it is urgent that the actions in terms of which these achievements are to be defined be removed from a formal, academic, literary context and re-stated in a fashion appropriate to the previous experiences of the student. This was not done in the experimental course. Its contribution, therefore, is obscured by ludicrous technical failures in communication.

The reports also indicate that the students, with disturbing frequency, have difficulty in actually conceiving the agricultural or other necessary processes which they carry out in

terms of chemical changes which occur. Many of their essays remain empirical treatises on problem topics in which the names of chemical substances, or what the students believe to be the names of chemical substances, occur. This is certainly further evidence that the reports are not an appropriate teaching device for these students, or at least, that they should have been partially replaced by experiences more suited to them rather than used as virtually the sole focus of student responsibility. This issue, however, is not related to the attainment of objectives in areas 8 and 9, but to the effectiveness of the total method. It will, therefore, be discussed, with other related questions, in the next chapter.

PART FOUR

EVALUATION OF THE APPROPRIATENESS OF THE NEEDS
APPROACH TO CLASSROOM INSTRUCTION

CHAPTER XIII

RANGE AND APPLICABILITY OF THE METHOD

The purpose of the study on which this dissertation is based, it will be remembered, was to develop a method by which science courses within specific departments of traditionally organized colleges or junior colleges might be adapted to the needs of contemporary college students without sweeping changes in administrative arrangements. In order to do this, a course in chemistry at the freshman level has been developed by the proposed method, described in detail, and appraised in terms of its effectiveness in attaining its objectives.

There is no experimental evidence concerning the applicability of the experimental method to the development of other science courses adapted to the needs of different students. Such generalizations as can be made on this issue must be derived from internal evidence, and conclusions must remain predictions. If so recognized, they may yet be of value.

Nothing in the definition of the method appears to limit its applicability. The pattern of needs-areas used as a basis for the classification of needs is extremely broad, while the individual needs stated within each area are flexible; different and appropriate choice of these might be made for any course. Areas of need may be omitted, as were areas 1 and 2 in the course described, if the content administratively assigned to the course has little to contribute to meeting needs within those areas. The behaviours in terms of which needs are defined may be chosen so as to be appropriate to almost any educational level. The study emphasized the college and junior college levels not because similar processes cannot be carried on at points further down the educational ladder, but because the division of course offerings into subject matter specialties is more nearly universal at the college level.

A question of great interest to subject matter specialists who might wish to consider the organization of courses around student needs is whether the objectives of traditional courses in

science are also obtained by the experimental course to an equal or greater extent than by traditional methods. Unfortunately, the results obtained by the study described indicate that they are not.

Three examinations provide information on this issue: the first semester final examination of the control group, which was administered to 46 pairs of students; the second semester final of the control group--actually designed as an ordinary examination covering only the portion of the course immediately preceding its administration, but pressed into service as a final and administered to the 16 pairs of students remaining when it was announced that most of them were about to be inducted into the army; and the American Council on Education Co-operative General Chemistry Test for College Students, Form 1942, which was administered to the 8 remaining pairs of students. The two control group examinations are reproduced in Appendix C. Scores on the control group first semester final are total right answer scores on all parts, except part six which has been omitted because it was not completed by most members of the experimental group. Scores on the control group second semester final are the sum of the right answer scores on the second portion and the rights-minus-wrongs score for the first, true-false portion. Scores on the American Council on Education examination were obtained according to the published formulae on page 16 of the test. The following portions of this examination were administered: Section A, "General Knowledge and Information"; Section E, "Application of Principles"; and Sections F and G, "The Scientific Method," thus providing a 61-minute sample of the 110-minute examination. Results are presented in Table 20.

The superiority of the control group on its own examinations is overwhelming. No critical ratios of quite this magnitude were obtained as indications of the superiority of the experimental group in the capacity to apply chemistry in any area of need, though, of course, no experimental group examination was used to measure achievement in a single area of need, and data obtained are therefore from much smaller groups of items. Evidently, however, there is little overlapping between the objectives achieved by the experimental and control groups.

On the American Council examination the superiority of the control group is uniform, but small. None of the ratios cited is

TABLE 20

COMPARISON OF RESULTS OBTAINED BY EXPERIMENTAL AND
CONTROL GROUPS ON EXAMINATIONS MEASURING
OBJECTIVES OF CONVENTIONAL
CHEMISTRY COURSES

Examination	M_x	M_c	6_{diff}	z
1st Semester Final. .	40.870	59.239	1.795	-10.17
2nd Semester Final. .	14.750	46.875	2.994	-10.73
ACE Examination:				
Part A.	10.625	18.125	3.55	- 2.11
Part E.	2.375	4.000	1.10	- 1.48
Parts F and G . . .	5.250	6.125	1.41	- 0.62
Total.	18.250	28.250	5.52	- 1.78

significant at the 5 per cent level with 7 degrees of freedom, and that for parts F and G is so small as to be virtually meaningless. However, in view of the greater similarity in content between the control course and the usual college chemistry course than between the experimental course and the conventional offering, it is likely that the superiority of the control group on this examination is real. Its small magnitude is undoubtedly due in part to the very small number of students involved in the measurement, and the relative ineptitude of both groups as measured by the Iowa test and corroborated by the low scores made by both groups. Apparently, instructors who attach greater importance to the learnings of the traditional chemistry program than to the ability to use chemistry in the solution of problems based on human needs would do well to continue to teach according to their accustomed organization. You do not achieve both better by the experimental method.

The experimental method, then, is applicable to those institutions which wish to alter their objectives from those of factual learning of a conventional course of study to the ability to apply science to the exigencies of daily living, without disturbing their administrative structure. It is not applicable to those institutions which, while concerned with the kind of objectives best met by the experimental course, remain committed to maximum learning of classical science. It is especially unsuited to institutions which wish to use a relationship to student inter-

est merely to motivate students toward a greater effort to learn academic science. Those components of the conventional chemistry offering which were not visibly related to the problems around which the course was organized were really eliminated as intended. The needs approach does not provide a framework on which all the customary adornments of science courses may be mounted. This does not mean that the objectives of the traditional and experimental program are irreconcilable. It is perfectly conceivable that course may be developed which will lead to the objectives of both better than either the experimental or control course led to its own. Even within the limits of the needs approach as described above--for example, in adapting a chemistry course to the needs of students who planned to earn their living as chemists--this might be achieved. In the ordinary adaptation of a science course to the needs of students who did not wish to become scientists, however, this would neither be attempted nor accomplished.

A second question of considerable importance had to do with the need for criteria by which one may decide whether behaviours in terms of which student needs are defined represent an appropriate level of learning or insight. It is true that there is nothing in the theoretical formulation of the needs approach which would be inapplicable to students at any educational level, provided they were sufficiently mature to carry on or anticipate obligations within each of the areas of need. But it is equally true that other factors besides theoretical relevance are involved in determining whether a particular behaviour is appropriate evidence that a student has learned to use science to solve a problem better than he could have solved it without. However obvious it may be that the behaviour sought would be useful in solving a problem on whose importance all are agreed, if that behaviour is not one which a student may reasonably be expected to develop in view of his intelligence, cultural background, maturity, or other antecedent factor, it is not an appropriate part of the course objectives. Furthermore, relevance is a meaningless concept unless it can be partially limited as to degree. To an expert scientist with a well-integrated knowledge of his field, each of its concepts is related in some degree to all others. These relationships are not apparent to lay persons, and while, if they were, they might be of some service in improving these persons'

power to live effectively, their attainment is usually impractical since it is physically impossible for everybody to become an expert in all the fields of specialization which impinge on their life. One must therefore set up an arbitrary procedure for deciding where to draw the line.

No provision was made in the experimental program either for the application of criteria other than relevance in determining the appropriateness of a behaviour or for defining the degree of relevance necessary. This is probably one of the fundamental reasons why the program was not more effective. A plethora of examples is available. In the preceding chapter the academic activities in terms of which maturity and democratic participation were defined were clearly inappropriate to the students, though such activities are excellent evidence of these characteristics in terms of students whose backgrounds place greater emphasis on literary skills and participation in the formulation of policy. The evaluation instruments measuring the ability to apply chemistry to the solution of problems of dairy farming were deemed poor because the behaviours which they required were related to these problems only by chains of theoretical reasoning which are artifacts of classical colloid chemistry, rather than by substantial increments in agricultural effectiveness which might be expected to proceed from their mastery.

The question of content is, of course, closely related to that of objectives. Just as no criterion for objectives except relevance to the areas of need was used in their formulation, no criterion except relevance to the problems whose solution the course took as its objectives was invoked in the selection of content. Here, likewise, the results were uneven and uncontrolled, contributing much to the ineffectiveness of the course. For example, consider the first need of area 3--the need to select metalware and plumbing for the home. This need is certainly relevant to effectiveness as a consumer, and it is certainly a need to which chemistry can contribute. But how much chemistry should the student be expected to know? At what point does it cease to profit him to increase his level of insight? Must he know the properties of various alloys? The electromotive series? The relation between chemical activity and atomic structure? Quantum mechanics? Chemical knowledge, like commodities in classical economics, has marginal utility; one reaches a point where a fur-

ther increment, achieved with as great labor as its predecessors, is but imperceptibly useful. Even definition of objectives in terms of minute behaviours hardly solves this problem, since what is needed is not a definition but a value judgment.

In the experimental course, the factor which actually determined whether or not particular content would be included was the capacity of the writer to perceive a relationship which he deemed important to the problem being discussed. His sensitivity to such relationships depends on his own knowledge, and hence the criterion of relevance was applied with exceeding unevenness. Since a major difficulty with the experimental course was its tendency to become too academic and to concern itself with relationships too remote and subtle for students who, for the most part, were accustomed to dealing only with the lowest degree of intellectual abstraction, it tended to fail in precisely those areas where the instructor was best informed. The consideration of dairy problems, overburdened with abstruse colloid chemistry, is a case in point.

In a truly need-centered approach to teaching students, these additional criteria of appropriateness of behaviours and of content are very much needed. It is indeed inconsistent to attempt to define one's objectives according to the needs of students and then to select one's content and method according to the intellectual meaning of the objectives without further regard to the characteristics of the students. Yet, there are, as yet, no effective technics for adjusting learning experiences at the college level to the student of limited academic ability, or more precisely, of defining objectives specifically and yet sufficient flexibly to suit the needs of all students. The experimental course was highly flexible in terms of interests and particular readings selected; it was as inflexible as any course in the kinds of demands it made on students and the channels by which they were permitted to demonstrate achievement. In the ordinary academic course this inflexibility is often less apparent, since objectives are not conceived in terms of particular changes to be produced in students, and if the results of instruction are often meaningless, they are usually normative. But in the experimental course many students, as demonstrated by the samples quoted from reports and the anonymous statements in the previous chapter, were actually forced into a Procrustean bed in which their verbal

skills, ability to abstract, and ability to synthesize learnings from several sources and several fields into logical formulations, were stretched far beyond their capacity to accommodate themselves.

The students' anonymous statements shed light on many methodological defects which must somehow be corrected if the experimental method is to achieve wide applicability. One-third of the commentators, according to Table 19, felt that the course, despite its complexity, failed to present certain fundamentals of chemistry which they needed in order to apply the science effectively to their chosen problems. This condition was the result of conscious, though apparently ill-advised decision. It had been the policy in the course to discuss only those facts and principles which could be related to the problems studied, and to discuss them only in connection with, not in advance of, the problems. This is at variance with the example of a chemistry course cited in Science in General Education,¹ in which fundamental theory is considered at the outset of the science course. Clearly there were many students who had severe difficulty in understanding discussions in which the meaning of the terms employed was derived en route. Furthermore, the content seems to have given far more theoretical explanations at many points than could be defended at the level of general education. Four of the 11 students who felt insufficient preparation had been given them to understand the course expressed "predominantly favorable" attitudes, and 2 expressed ambivalence, indicating that this alone was not highly disturbing to most of the students who felt it. Six of the 11 also felt the course to be highly practical. Presumably, the students raising this objection tended to accept the objectives of the course, and felt that the course organization made it more difficult than necessary for them to reach these objectives.

The 3 students who felt unprepared to take further chemistry all expressed predominantly or totally unfavorable attitudes, though 1 regarded the course as practical. The comments of these students were more strongly emotionally toned than were those of any other group. One comment, number 28, is bitterly resentful; Father Coughlin, if he found himself, through circumstances beyond his control, attending services in a synagogue, might express himself in similar terms. Since it has been demonstrated that

¹Commission on Secondary School Curriculum, op. cit., pp. 465-76.

pre-requisite courses, even when planned by college administrators, frequently fail to contribute anything to the success of students in later courses, it is clear that the students had too little data to justify them in predicting their failure in courses whose demands were quite unfamiliar to them. The belief betokens, therefore, chiefly a feeling of great insecurity in the experimental course and a rejection of it.

Four of the 33 commentaries stated that the language used by the instructor was not comprehensible. These students were evenly divided between the "predominantly favorable" and "predominantly unfavorable" groups. This is rather surprising, since it seems that so legitimate a complaint should have aroused more antagonism. A person who habitually addresses groups in language which they do not understand has no place in teaching; if his voice is excellent he may find success in grand opera. Other faults may be justified, or explained, by considerations of philosophy, but this one cannot be.

A particularly interesting comment, of the "predominantly unfavorable" group, is number 15. Particular attention is called to it since it is couched in such subtle language, and seeks to be so penetrating, that it has little in common with the other comments and appears in none of the ten rubrics of Table 3. This student feels that the course situation is not sufficiently structured; that he has learned as much as in more conventional courses, but that he does not know what he has learned as clearly. This seems to be a rather valid criticism, which arises no doubt from the rather contrapuntal arrangement of content in certain areas. It is probably true that for most students a more discrete organization of material is preferable, even at the cost of showing fewer interrelationships.

We may therefore conclude that, although the experimental method is not limited to any level of education by the terms in which it is defined, or by its fundamental philosophy: as practiced in this chemistry course, it was adapted to the learning technics of only the best students, in the common academic sense of the term. In order to take broader advantage of the possibility of the method, needs must be defined at various levels in terms of some behaviours which are possible to all students, and instruction must use learning technics which present less formidable barriers to the verbally ungifted. Specifically, concepts such

as "democratic participation" and "maturity" must include behaviours consistent with the previous background of the student; behaviours demonstrating the ability to apply chemistry content to the solution of problems must include some sufficiently elementary to lie within the scope of the less gifted student, and yet sufficiently discrete and distinguishable from the behaviours of persons ignorant of chemistry to provide evidence of real learning. Technics of instruction must include procedures which do not require of students the scholarly capacity to integrate data from published sources into a written report of comprehensive character. The concept of student need must be supported by a realistic understanding of the capacities of the students whom one is teaching so that it may guide instruction as well as the selection of content, and it must assist one in selecting, not that content which is relevant to the most perfect solution of a problem which the instructor can imagine, but that which can be used by students with reasonable efficiency at their own developmental level.

If there are not theoretical limits to the range in educational level to which the experimental course is applicable, are there limits to the cultural range? In the opinion of the writer there are. These limits result from the difference in educational aim characteristic of different cultures. For the validity of any procedure which attempts to adapt a science course to the needs of students depends upon assumptions which are closely related to the culture. Such a procedure assumes that the major function of education is to assist students to meet the problems which they may be expected to encounter in the course of their living, and that the degree to which this has been done may be inferred from overt changes in student behaviour, even if this behaviour is only performance on carefully designed tests. It also assumes that the interests of students, and their beliefs as to how the course should be conducted, are important factors which the instructor must consider in his planning.

Comparatively few colleges take this view of the educational function. More, believe that the major function of education is to transmit the culture of past, or to provide a general education based on mental discipline and familiarity with characteristic organizations of knowledge, or to train an élite for professional or social leadership, or to reveal to mankind the

truths prized by a hierarchy based on transcendental grounds. Even more exist without any consistent conception of the educational purpose to which they are committed and have thus become degree-granting vested interests of their staffs and local communities.

Each of these educational viewpoints reflects an aspect of our culture. None of them would find the adaptation of science courses to student need, by the method described in this document, particularly useful to their purposes. The process is not relevant to their goals; it does little which they are concerned with doing. The applicability of the method used in developing the course in inorganic chemistry offered experimentally to the agriculture students of Oklahoma A & M College is therefore restricted to that component of our culture which holds that truth and reality are created uniquely for each individual through his own experience, which can never duplicate that of the past and is not primarily oriented to the past; to those who believe that the necessity that each man bear the burden of his own destiny grants him a right to a voice in its control; and to those who hold that the welfare of the social order is best advanced by contributing to the development of all the accessible individuals in it.

CHAPTER XIV.

THE VALIDITY OF THE ASSUMPTIONS OF THE NEEDS APPROACH

In Chapter II, five assumptions fundamental to the use of the experimental method in the adaptation of science courses to the needs of students were identified and discussed. These were:

1. Student welfare is the focus of educational effort.
2. Learning influences behaviour.
3. The basic faith in insight and rational use of comprehended fact in determining choices of behaviour remains the cornerstone of educational planning.
4. The objectives of a course are determined by the changes which it is intended to produce in students rather than by the subject matter peculiar to the department in which it is offered.
5. Learnings are chiefly useful in situations similar to that in which the learning occurred.

It was not the purpose of the experiment described to test these assumptions. Indeed, the first and fourth cannot be tested, since they derive from one's subjective belief about the function of education, while the remaining three are regarded by most authorities as among the basic, though surely not immutable, truths of educational psychology. Yet, though nothing which was done in the experimental program will prove or disprove these five statements, their relationship to the program should surely have been clarified in the development of it. In this, the final chapter of the dissertation, it seems desirable to examine the ultimate status of this relationship.

Student welfare remained throughout the experimental course the focus of educational effort. The focus was, however, considerably clearer with respect to content than to technique; in the latter, also, the image occasionally appears to be inverted. Little can be added here to the statements of the previous chapter with respect to this point. In so far as the course content was restricted to material demonstrably relevant to student problems, a fairly consistent record was made. It cannot be claimed, how-

ever, that content was restricted to material useful to these particular students, or that it was made available by especially effective teaching procedures. With respect to these, student welfare got perceptibly out of focus.

As a result of these technical deficiencies, a large proportion of the students, as stated in the two previous chapters, developed strong feelings of insecurity in the program. It is perfectly true that people may be frightened by changes which are not only beneficial but essential to their survival; this, indeed, is the basic factor in economic and governmental problems today. Nevertheless, a feeling that one is threatened is, in the absence of contrary evidence, basis for an inference that one's welfare is not being advanced; at least, not in a way to which one is ready to consent.

If one accepts the implication that the ability to solve problems related to one's needs is an important factor in determining welfare, and if one agrees that the examinations designed for the experimental group measure such ability, there is no doubt that the experimental course advanced student welfare. It did not advance it as much as it would have if content and objective had been more appropriate to the behavioral level of the students. But some attention must also be paid the relationship between student participation and student welfare. Two questions are clearly involved in this issue: Does student participation in the determination of course content and policy advance student welfare? and, Were methods by which the experimental course sought to provide for student participation effective?

The first of these questions can perhaps be better answered by reference to fundamental philosophy than by scientific investigation. The writer can only state that he would be unashamedly hostile to any assumption that one human being is capable of determining totally the best course of action or course of study for another, regardless of their roles in any hierarchy. Such an assumption is at variance with the basis of democracy. The second question is amenable to investigation, and the foregoing account of the experimental procedures justifies a conclusion that the provisions for student participation functioned largely in a negative way. That is, they permitted individuals to avoid the study of problems which did not interest them in favor of others which did, and they permitted students who were disturbed

by the more superficial technical difficulties of the course to bring pressure to bear to have those difficulties eliminated. But they did not provide a really effective way for students to introduce new objectives and new teaching methods into the course. Worse yet, they did not provide any way of sharing the experiences of individual students among the group. In the original formulation of the experimental method, it had been planned that all the students choosing to investigate a particular problem should form a panel to discuss this problem before the class, with the instructor acting as discussion leader. This procedure was tried by the writer in a previous teaching situation with disastrous results, since most students are incapable of organizing material for effective teaching until they have been rather carefully taught to do so, and the class bitterly resented their ineptitude. The reports written by the students in the experimental group were little other than "themes" for which a rather wide choice of subjects had been offered. They were never presented to the group, and individual students had no opportunity to prepare anything which actually became material of instruction. It must be concluded then that if student participation is important to the advancement of student welfare, more effective means of providing it than those offered by the experimental course must be devised. This raises the question whether time should be taken to train students in effective organization and presentation of the results of their investigation; or whether the reports, on whose instructional value the analysis in the previous two chapters cast serious doubt, should be largely eliminated in favor of such projects as student participation in devising visual aids. The instructor is inclined to favor the latter course, while leaving the preparation of written reports as a possible choice for those students who find them an appropriate means of self-expression. The possibility of effective student presentation of material at the college level should not, however, be dismissed. One need only remember that it cannot reasonably be expected of all students, and to make provision for contribution by less verbally gifted class members.

The second assumption, that learning influences behaviour, is clearly not applicable to the experimental course alone. Conventional science courses, however, do not conceive their objectives in terms of relatively specific changes in behaviour, so

this assumption is more important to the experimental than to the control course. The comparative examination results demonstrate, granted the validity of the items, that the experimental course did tend to establish in students, to a greater degree than the control course, those behaviours which were designated as the course objectives. It seems likely that the observed differences would have been greater, however, if less academic behaviours had been chosen as evidence of the ability to use chemistry to meet the various needs included in the classification in Chapter IV. This question has, however, been fully discussed in previous chapters.

Our third assumption deserves careful scrutiny. It is precisely in order that "rational use of comprehended fact" may determine choices of behaviour more effectively that the experimental method has been developed. In the writer's judgment the foregoing evidence justifies a conclusion that the experimental group students did find in insight and comprehended fact an instrument by which they might choose more effective courses of action. The examination results support this inference. The student comments support it more strongly. More of the commentators, in a wholly unstructured situation, regarded the course as practical than agreed on any other characteristic of it. Practical is simply not a word which seems appropriate in describing a conventional science course; such a course can be neither practical nor impractical because it does not start out to do anything specific by which it can be judged, and also because it is commonly presented with the attitude that it deals with something outside itself which cannot be changed whether valuable to people or not. But a course which students regard as practical probably is practical unless it is full of misinformation, since what is needed to make a course practical is primarily recognition by students that it is intended to be used rather than learned. On the negative side, however, one must admit that only comprehended fact can determine behaviour, and the experimental method was more effective in selecting useful facts than presenting them.

With respect to the fourth assumption, the experimental course was almost wholly consistent. Certainly, its objectives were determined by student need, even if they were not always defined in terms of the most appropriate behaviours possible. And, certainly, the objectives achieved by the experimental course were

different from those achieved by the control course. The superiority of the control group on its own examinations demonstrates that as clearly as does the superiority of the experimental group on most of the groups of items on its examinations. There was, in fact, very little overlapping in achievement by the two groups, and only an institution committed to this fourth assumption could rationally accept the experimental procedure. There is, however, one factor which was not eliminated from the experimental procedure, and which led to some deviation from this assumption in the selection of content. This is the sanctity with which certain aspects of the chemistry curriculum are endowed by nearly all persons trained in chemistry, including the writer. The experimental procedure was supposed to lead to the elimination of all content not clearly useful in the solution of problems of importance to students, however hallowed its place in the chemistry curriculum. But, as stated in the previous chapter, there was a considerable tendency to regard as useful in the solution of a problem all relevant material which a person trained in chemistry could perceive as related to it. Rare indeed would be the chemistry teacher with the self-discipline needed to exclude from his course a discussion of the periodic table, or the nature of acids, bases and salts; for even if these things were not needed to solve a problem, they are logically connected to the problem, and a chemistry teacher feels guilty if they are altogether excluded. It is a sad truth that the act of revolt, because it takes cognizance of the power of existing institutions, tends almost always to commit the revolutionary, despite himself, to the moral and aesthetic values of his opponents. Thus the Mexican government has made a national museum of the Palace of Chapultepec, which is surely one of the most hideous buildings in North America. Thus the Soviet Union challenges the capitalist bases of ownership while attempting to surpass the culture of capitalism in the purity of its materialism. And thus the chemistry teacher, however radical his philosophy, continues to discuss the interior of the atom in minute detail. Only objective criteria of the degree of relevance necessary to justify inclusion of content in a course adapted to student need can eliminate this difficulty.

With respect to our fifth assumption, "Learnings are chiefly useful in situations similar to that in which learning occurred," the relation of the experimental course has been most

complex. For, in the most obvious sense, the situation of the experimental course was as different as possible from the real situation in which chemistry is to be applied. The context was wholly academic; the procedures by which students investigated their chosen problems required library and laboratory facilities which would never again be available to them. While it does not seem that it would be desirable to forego the use of these facilities in a college course, it must be recognized that they do introduce an element into the learning situation which will make transfer more difficult.

However, the most important consequence of this fifth assumption was the sequential organization of the course content. Because of the assumption, no preliminary period of instruction in the vocabulary of chemistry or in the theoretical principles around which it is usually organized, was given. This raises two important questions: (1) Is it really more efficient to learn concepts in use and thus obtain relevance to need while greatly enhancing difficulty in understanding because of vocabulary difficulty? and (2) To what extent did the experimental course really defer the introduction of chemical concepts until they were needed in the solution of problems, and would it be possible to do so to the same or to a greater degree with other science courses?

With respect to the first question, opinions differ. As mentioned in Chapter XIII, Science in General Education¹ cites a chemistry course in which a period of fundamental study precedes the consideration of problems, although this procedure seems to be inconsistent with the view of the authors. The course cited was developed by Ahrens, Bush, and Easley in the Denver school system, and their text, Living Chemistry, which is similar in viewpoint to that underlying the needs approach, follows the same plan of organization. Furthermore, the exploratory group whose experiences are described in Chapter V and whose members had all taken the first semester of the traditional program, seemed to adapt itself to the experimental procedure with greater ease than the experimental group itself. In particular, almost all the reports written by members of the exploratory group are more scholarly documents than those written by members of the experimental group. How much of this superiority is due to the fact

¹Ibid.

that all the exploratory group members were carefully chosen for suitable temperament from a group of volunteers, it is not possible to say. It must also be noted that the most frequent complaint of the anonymous student commentators in the experimental group was that they lacked the fundamentals of chemistry.

Despite the mass of this evidence, the writer is inclined to hold to his original position that, in adapting a course to student need, subject matter should be introduced only as it becomes useful in solving students' problems. The reason for this stubbornness is that relevance to student problems is the essential criterion by which the eligibility of content for inclusion in such courses is determined. That this criterion is inadequate, in the absence of supplementary criteria of degree and comprehensibility, has already been stated. But without this criterion one is taken directly back to the classical science curriculum. It has always been the policy of most science teachers to include in their courses some discussion of the applications of the facts and principles which formed the basis of their courses. But they did not restrict themselves to the discussion of those facts and principles which might be useful to students. It is this attempt to include only that which is demonstrably useful which most sharply distinguishes the needs approach.

It is, of course, possible to invoke the criterion of usefulness in order to identify the theoretical concepts worth including in the course, and then to isolate these concepts and present them in a separate portion of the course prior to the consideration of problems. This, however, presupposes that the instructor can predict in advance what problems will be considered, which he can hardly do if the course is to be truly responsive to variations in student interest. Or he might carefully choose those concepts and facts which seem so fundamental that their usefulness may be assumed, regardless of the pattern of problems chosen for study. There are undoubtedly some such terms, facts, and concepts which it would be fantastic to omit from any chemistry course--the concept of an element or a compound, or of conservation of energy, for example. But a separate presentation of these concepts would surely weaken the conviction, which the needs approach seeks to create, that chemistry is a classification of tools to be put at the disposal of students rather than an objectively real physical entity. It would also greatly predispose

the instructor to yield to the tendency to include all that is most respectable in the chemistry curriculum, which was mentioned earlier in the chapter with respect to the fourth assumption.

Our second question, however, remains unanswered, and in answering it, we shed some doubt on the possibility of rigid adherence to the avowed policy of the needs approach. For, was chemical content introduced into the experimental course only as needed, or, even if it was, did not a disproportionate amount of it fall due when the very first problem was considered, thus indicating that there is much less difference in practice than in theory between the policies of presenting or withholding a previous theoretical discussion? The first problem considered was the choice of a suitable metal for household installations. This problem was no more important intrinsically than any other in area 3. But it was discussed for an entire month, and in the course of the discussion a much more complete account of atomic structure, the periodic chart, the electromotive series, oxidation and reduction, and other theoretical concepts was given than is given in most courses in freshman chemistry. True, no other problem in area 3 would have permitted this. But it is precisely for this reason that this problem was first discussed. Evidently, there is a tendency even in the needs approach to arrange problems in such an order as to provide a necessary theoretical background and vocabulary as soon as possible.

Nevertheless, there is still a wide difference between the policy followed in the experimental program and that of separating out one's background discussions into a sort of brief introductory theoretical course. In the experimental program fundamental theory continued to be introduced throughout the year as each problem was discussed, though not as profusely as at the outset. And the writer is inclined to believe that this is as it should be. Science, like nations, has its language; and the easiest way to learn a language seems to be by use, not in anticipation of use. The deficiency of the experimental course seemed to be, not that its fifth assumption is unsound, but that its demands were not adapted to the condition of the students at the time the demands were made. The most effective teachers of French no longer start their students with a memorization of the rules governing regular verbs, the declensions of the irregular verbs, and the position of phrases modifying either. They begin with simple reading and com-

position. But they do not begin by reading Proust's A la Recherche du Temps Perdu aloud to the students, and assuring them that they will presently begin to catch on to it. What is needed is a way to develop a scientific vocabulary and scientific insights in use without trying to present materials as though these things already existed.

In the foregoing document a procedure for adapting courses in science to the better service of students has been described. An attempt was made, in the first chapter, to analyze the social trends which have rendered traditional college science programs incapable of serving their present clientele effectively. In the second, the writer's assumptions concerning the learning process and the mission of education, on which his proposed procedure is based, are made explicit. The next five chapters were concerned with a description of the application of the procedure to the development of a particular science course. A similar number of chapters were then devoted to an appraisal of the success of this course in achieving its objectives. In the last two the writer has sought to estimate the range of applicability of his procedure and to define carefully the final status of his original assumptions.

It will have been clear to the reader that no ultimate and final solution to the problem of effective science teaching has been offered here. On the contrary, the course in chemistry herein described was marred by so many flaws in pedagogical technic that the consequences of the educational philosophy of the needs approach are occasionally obscured. Circumstances beyond the control of the author, moreover, so depleted both experimental and control groups before the final measurements of the study could be made, that certain comparisons, which should have yielded definite conclusions, actually given only indications from which the possible influence of chance factors can now never be eliminated.

Nevertheless, certain conclusions have been drawn. Experimental group students were demonstrably superior to control group students in their capacity to apply chemistry to all but one of the problems chosen to represent effective consumption of goods, and to apply chemistry to several of the problems chosen to represent the intelligent support of necessary public services; they are superior to the control group in their performance on items

measuring achievement in each of these areas when grouped as a whole. Students of the experimental group are demonstrably superior in their ability to apply chemistry to problems of pest control and problems related to soils. There are no indications of inferiority to the control group in any area of need considered in the course. There are, however, indications of inferiority to the control group on a published examination measuring the traditional objectives of chemistry courses, and there is proof of inferiority of the experimental group on the control group's own examinations. The separate and unique consequences of the needs approach as here defined have been identified and appraised. And even the technical deficiencies of the writer as a teacher have seemed, in a sense, to clarify the issues involved. They show very plainly the need for complete philosophical consistency if, once having left the well-established trails of educational tradition, one is to reach one's objective.

One cannot say that science courses adapted to the needs of students are superior to courses which are not, unless one first stipulates what one expects to accomplish by the teaching of science. But that which is gained by such adaptation has been demonstrated. So has that which has been lost.

The reader's decision, then, as to whether he accepts or rejects the procedures described here, will probably depend less on their merit as teaching methods than on his conception of the role of science teaching at the junior college level. There are many different conceptions of the obligation of the college to its sub-specialized students. The writer does not pretend to find merit in all of them, though the right of the holders of each view to their chosen position must surely be respected. But this work will be of value chiefly to those educators who hold that the first obligation of the school is to make students healthier, happier, more effective people, as nearly on their own terms as socially practicable. The writer hopes that they will find his thinking of some value in stimulating their own, and that they will profit particularly by the errors which he, with generous abandon, has made in their stead.

APPENDIX A

SAMPLES OF MATERIALS PREPARED BY THE INSTRUCTOR AND DISTRIBUTED
TO THE STUDENTS IN THE EXPERIMENTAL GROUP, INCLUDING ALL
EXAMINATIONS DESIGNED TO MEASURE THE OBJECTIVES OF THE
EXPERIMENTAL PROGRAM. THIS MATERIAL IS REPRODUCED
ESSENTIALLY AS DISTRIBUTED ..

EXAMINATION A
FIRST EXAMINATION
Chemistry 134

Maximum time, twenty minutes.

Part One

Directions:

In each of the questions asked or implied below, select those of the possible answers which are correct, and in the form on your answer sheet bearing the same number as the question, blacken the spaces having the same numbers as the answers. Pay no attention to such words as is or are as determining the number of possible answers, each question may have any number of answers from one to five. Of course, many of the suggested answers are untrue statements. If you finish any part of the test before the maximum time allotted for it, GO ON TO THE NEXT PART. If you have not finished any part of the test when the time allotted for it has elapsed, GO ON TO THE NEXT PART. You may return to the part you could not finish if you have any time left over from either of the two later parts.

1. Lead pipe is very seldom used in plumbing installations now, because:
 1. Lead is so far above hydrogen in the electromotive series that it reacts rather rapidly with water.
 2. Lead is slightly above hydrogen in the electromotive series, and reacts slowly with water.
 3. All lead pipe available is needed in the war effort for the manufacture of lead pipe cinches.
 4. Lead salts are highly poisonous and have a cumulative toxic effect on the body.
 5. Lead is too brittle to be worked easily.
2. Among the reasons why copper pipe is more useful in plumbing installations than aluminum are:
 1. The electrons in the outermost orbit of the copper atom are more tightly held than those in the outermost orbit of the aluminum atom.
 2. More quantum numbers can be written for electrons in the fourth orbit than in the third.
 3. There are more protons in the copper nucleus than there are electrons in the outermost orbit.
 4. There are more neutrons in a copper nucleus than in an aluminum nucleus.
 5. Aluminum tends to become coated with a film of its oxide.
3. Copper smelting is often a menace to surrounding agriculture because:
 1. Copper is especially toxic to plant life.
 2. Large quantities of sulfur dioxide are often produced.
 3. Essential constituents of the soil are removed in copper mining.
 4. Toxic arsenical fumes often accompany the process.
 5. The waste products of the smelter tend to pollute surrounding streams.
4. The properties of magnesium which cause it to be valued as a major constituent of alloys for use in aircraft are:
 1. Its high specific gravity.

Examination A, First Examination--Continued

2. Its high resistance to corrosion.
3. The ease with which it may be produced from its ores.
4. Its low density.
5. Its high malleability when pure.
5. If copper pipe is used to conduct water into the kitchen, it is quite certain that:
 1. The copper will not be attacked as long as only pure water is led into the pipe.
 2. If any materials which corrode copper should get into the water, it is possible that the household would be poisoned.
 3. If the water were slightly acidic, cast iron pipe would be more serviceable.
 4. Even if the water were acidic, it could only attack the copper if it also contained oxidizing agents.
 5. Since most world sources of copper have fallen into enemy hands, Leon Henderson will send a man to take the pipe away.
6. One may truthfully say of the reaction between water and most metals that:
 1. Few metals will corrode if kept perfectly dry.
 2. It is the undissociated water molecules which are responsible for most corrosion.
 3. It is the hydronium ions which are responsible for most corrosion.
 4. Hot water is more corrosive to metals than cold.
 5. The corrosion of metals by water results in the introduction of metal cations into the water.
7. The purification of crude copper ingots is often a profitable process quite apart from the improvement in the quality of the product because:
 1. Gold and silver are often recovered from the electrolytic sludge.
 2. The slag obtained from the reduction furnace is often very rich in phosphates.
 3. More than enough electrons are obtained by loss from the copper to carry on the electrolysis.
 4. The water in which the ingots are leached develops valuable fungicidal properties.
 5. The carbon monoxide formed in the furnace can be sold to the penitentiaries in the western states in which the mines are located for use in lethal chambers.
8. Moving steel parts are often case-hardened, because:
 1. A high carbon content increases the hardness of steel.
 2. Steel which has been annealed in a case is tougher than steel which has been allowed to harden in air.
 3. Steel which has a high percentage of carbon throughout is often more brittle than steel with a low carbon content.
 4. Case hardening is an indispensable step in the tempering process.
 5. The melting point of steel is greatly raised by the case-hardening process.
9. If certain of the following facts were true of aluminum (as, indeed, some of them may be), it would be much less suitable for kitchen use:
 1. If there were only one-third as much aluminum in the world as there is.
 2. If aluminum did not become coated with a film of its oxide on exposure to air.

Examination A, First Examination--Continued

3. If aluminum had thirteen less protons in its nucleus.
4. If aluminum fornostroside were less easily electrolyzed.
5. If aluminum lost electrons much more easily than it does.
10. The formation of tarnish on silver surfaces would not occur if:
 1. Silver were a more active element than aluminum.
 2. The silver could be kept away from substances containing sulfur.
 3. Silver were not washed in water containing oxidizing substances.
 4. Copper were alloyed with the silver.
 5. The formation of a coating of silver oxide were prevented.
11. The development of aluminum as a common household metal was greatly delayed because:
 1. The proper grade of coke for the reduction of aluminum oxide is very rare.
 2. Aluminum is not very widely distributed in nature.
 3. Aluminum loses electrons much more readily than hydrogen.
 4. Electrolyses are ordinarily carried out in water solution.
 5. In the hall process, the rare mineral, cryolite, is rapidly consumed.
12. With regard to the electrical conductivity of metals it can be said that:
 1. A smaller weight of copper wire would be required to conduct a five ampere current fifty miles than would be true if the wire were made of any other metal.
 2. The less active a metal is, the better conductor it will be.
 3. Small traces of impurities greatly impair the conductivity of copper wire.
 4. A copper wire is a better conductor of electricity than an aluminum wire of the same cross-sectional area.
 5. The constant passage of electrons along a wire will result in permanent changes in its structure.
13. Silver would probably soon be in use as a lining for food cans except that:
 1. A thicker lining of silver would be needed than is needed with tin.
 2. America is largely self-sufficient with respect to its tin needs.
 3. Silver is so active that it would be attacked by acidic foods.
 4. [Omitted.]
 5. The price of silver is artificially maintained at a prohibitive level through political influence.
14. Which of the following factors are involved in the resistance of galvanized iron to atmospheric action?
 1. Galvanized iron is covered with tin, which is a much less active metal.
 2. Galvanized iron is coated with zinc which is more active and is attacked instead of the iron.
 3. Zinc tends to become coated with its own oxide when exposed to air.
 4. Galvanized iron is coated with zinc, which is a less active metal.
 5. If any of the iron should rust, electrons forced by the zinc on the ions thus formed would restore it to a metallic condition.

Examination A, First Examination--Continued

15. If the world's most productive zinc fields were to fall into enemy hands, the most immediate consternation would probably be felt by the citizens of:
1. Timmins, Ontario.
 2. Adelaide, Australia.
 3. Archangel, Russia.
 4. Sacre, Bolivia.
 5. Tulsa, Oklahoma.

Part Two

Maximum time, fifteen minutes

Matching Set.

Below you will find a list of common alloys, followed by a list of descriptive terms which might apply to them. In each of the forms on your answer sheet bearing the same number as an alloy, blacken the spaces bearing the same number as the descriptive term which you think applies to that alloy. For example, if you are so cynical that you think sterling silver is mostly nickel, you will blacken space 3 in form 130. Any answer may be used any number of times, and any question may have any number of answers, or none. The term major constituent is taken to mean a constituent consisting of half or more of the total alloy, not merely an important constituent.

- | | |
|-----------------------|---|
| 121. Woods metal. | 1. Major constituent is iron. |
| 122. Aluminum bronze. | 2. Major constituent is copper. |
| 123. Common steel. | 3. Major constituent is nickel. |
| 124. Invar. | 4. Major constituent is magnesium. |
| 125. Plumbers solder. | 5. Contains much bismuth. |
| 126. Nickel silver. | 6. Contains much zinc. |
| 127. Dow metal. | 7. Contains much lead. |
| 128. Ferrobullion. | 8. Contains much nickel, but less than half. |
| 129. Brass. | 9. Is valued for its very low density. |
| 130. Sterling silver. | 10. Is valued for its low coefficient of thermal expansion. |
-
11. Is made from a common form of an unalloyed metallic element by oxidizing most of the carbon which is introduced as an impurity in the process by which this element is isolated from its ores.
 12. Valued for its high magnetic permeability.
 13. Derives its usefulness from its low melting point.
 14. A very inactive alloy, not at all affected by the strongest non-oxidizing acids, but tarnishes rather easily.
 15. Made by replacing the tin used in one of the oldest of alloys by a metal much more recently made commercially available.

Part Three

Maximum time, twenty minutes

Mrs. Gordon Esterhazy has been forced by the present servant shortage to assume managership of her own kitchen. Unfortunately, when the patriotic organization of which Mrs. Esterhazy is chairman, launched its colossal scrap drive two months ago, she felt obliged to support this enterprise by donating all her kitchen utensils, and must now replace them. In doing so, she makes the

Examination A, First Examination--Continued

following choices:

136. A copper teakettle.
137. An aluminum skillet for frying.
138. Cast iron pots and pans for boiling and stewing.
139. Enamelware vessels for pickling.
140. She refuses to purchase lead bowls for keeping cooked foods in the refrigerator.

Below you will find listed a series of reasons why Mrs. Esterhazy might have made these five choices. Some of these reasons are false, some are true. They bear two sets of numbers, (61-75) and (1-15). Looking at the first set of numbers first, please blacken the spaced marked T in the form on your answer sheet bearing the same number, if you believe the statement to be true, and the space marked F if you believe the statement to be false.

Then, no matter how you marked them, assume each statement to be true, and consider whether, in this case, it would have supported Mrs. Esterhazy in any or all of her five choices. If you believe that this statement, assumed to be true, would support Mrs. Esterhazy in one or more of her choices, blacken the space bearing the same number as the second number of the reason in the form bearing the same number as the choice.

For example, suppose there appeared below the following possible reason, with these numbers:

87-7 Cast Iron can never be attacked by any sort of water solution. This is a false statement. You would therefore blacken space F, in form 87. However, if it were true, it would certainly be a good reason for the choice which Mrs. Esterhazy made in statement 138. Therefore, you would blacken space seven in form 138.

THE REASONS

- 61-1 The use of complex metal silicates as coatings for metalware results in a highly impervious and resistant utensil.
- 62-2 The oxide film with which aluminum becomes coated is easily attacked by hot grease.
- 63-3 Some metal ions are electrically neutral.
- 64-4 There are more protons in the nucleus of an iron atom than there are electrons in its outermost orbit.
- 65-5 Many soluble metal compounds can be ingested without harm.
- 66-6 The activity of certain metals is inhibited if silicon is present in its surface layer.
- 67-7 The salts of some metals are poisons whose effect on the body is cumulative.
- 68-8 Metals which are only slightly above hydrogen in the electromotive series may nevertheless react with water if given long enough.
- 69-9 Copper will drive silver ions from a solution containing them.
- 70-10 Hydronium ions will not occur in fats appreciably under the conditions of cooking.
- 71-11 Metals below hydrogen in the electromotive series cannot react with pure hot water.
- 72-12 Aluminum is too inactive to react with foodstuffs.
- 73-13 Coatings of mixed metal silicates are not susceptible to thermal fracture.
- 74-14 When a lead atom loses electrons, it becomes a lead ion.
- 75-15 Metals denser than aluminum can react only with strong oxidizing agents.

EXAMINATION B
SECOND EXAMINATION
Chemistry 134

This examination will be timed. If you finish any part of the test before the maximum time allotted for it, GO ON TO THE NEXT PART. If you have not finished any part of the test when the time allotted for it has elapsed, GO ON TO THE NEXT PART. You may return to the part you could not finish if you have any time left over from either of the two later parts.

Part One
Maximum time, fifteen minutes

In each of the questions asked or implied below, select those of the possible answers which are correct, and in the form on your answer sheet bearing the same number as the question, blacken the spaces having the same numbers as the answers. Each question may have any number of answers from none to five. Many of the suggested answers are untrue statements, of course.

1. Solutions of which of the following substances might be useful as antiseptics, if you were to cut your hand?
 1. Metaphen.
 2. Mercuric chloride.
 3. Sodium hypochlorite.
 4. Aluminum sulfide.
 5. Merthiolate.
2. Which of the following drugs exercise specific action against the organisms which cause the diseases for which they are given?
 1. Thiamin chloride.
 2. Sulfathiazole.
 3. Sodium bicarbonate.
 4. Quinine.
 5. Salvarsan (arsphenamine).
3. What of the following substances would you not be surprised to discover in a tooth powder?
 1. Soap.
 2. Calcium carbonate.
 3. Sugar.
 4. Sodium cyanide.
 5. Formaldehyde.
4. The prophylactic injection against typhoid fever may not properly be called a serum because:
 1. Serums are sometimes given to cure diseases, but never to prevent them.
 2. The material injected is not derived from the blood of an animal.
 3. It is possible to contract typhoid even after having been injected against it.

Examination B, Second Examination--Continued

4. The injection against typhoid fever has to be given successively, on three occasions, rather than all at once.
5. The injection consists of killed germs suspended in salt water.
5. Which of the following germicides or antiseptics act by coagulating protoplasm, with little or no selective action?
 1. Hydrogen peroxide.
 2. Phenol.
 3. Mercuric chloride.
 4. Zonite.
 5. Bergdorf-Goodman solution.
6. It would be a simple matter to provide a mouthwash positively guaranteed to kill all bacteria in the mouth if:
 1. Sulfanillamide and allied drugs were cheap enough to use in a mouth wash.
 2. An infra-rotatory specific, capable of astrigating bacterial mutation could be discovered.
 3. The person who used the mouthwash did not mind having his tongue and palate burned to death by it.
 4. The alkalinity of saliva were not so well protected by buffer salts.
 5. The protoplasm of bacteria were totally unlike that of people.
7. Among the most serious defects of lead white as a pigment for house paints to be used inside the house are:
 1. Its exceedingly low covering power.
 2. Its tendency to poison those who apply it,
 3. Its dull, off-white color.
 4. The fact that the process by which it is made is so new that it is not entirely reliable.
 5. Its tendency to darken when exposed to small concentrations of hydrogen sulfide over a period of time.
8. Among the advantages of chromic oxide as a paint pigment are:
 1. Its delicate coral color which cannot be duplicated in any other pigment.
 2. Its durability and resistance to chemical action which surpass those of other green pigments.
 3. The ease with which it may be prepared by precipitation from a solution of sodium ferrocyanide.
 4. The ease with which it may be resolved into its component parts, Prussian blue and chrome yellow.
 5. The simplicity of the laking process by which it is made.
9. Pyrex glass differs from ordinary glass chiefly in:
 1. Its abnormally low index of refraction.
 2. The substitution of borate for part of the silicate of which glass is commonly made.
 3. Its abnormally low coefficient of thermal expansion.
 4. Its resistance to mechanical breakage.
 5. Its high content of sodium carbonate.
10. Which of the following components are found in calcimine when it is mixed, ready to be applied, but are not found in paints?
 1. Water.
 2. Linseed oil.
 3. Pigment.
 4. Calcium carbide.
 5. Glue.

Examination B, Second Examination--Continued

11. Earthenware cups and saucers differ from those made of fine china chiefly in that:
 1. They are fired at a lower temperature.
 2. They are less completely converted to fused silicate in the course of manufacture.
 3. They are more expensive.
 4. They are always modeled, never cast into a mould.
 5. They cannot be glazed.
12. If you were given an injection of diptheria toxin-antitoxin in the course of a routine schoolwide immunization, the immunity or injection which you got from it would differ from the immunity or injection you would get if you were given an injection of diptheria antitoxin after an assumed exposure to the disease. Among the ways in which this former immunity would be different are:
 1. It would not last as long.
 2. A large part of it would be due to products manufactured in your own body.
 3. The injection would be derived from the blood of an animal, probably a horse.
 4. The injection would contain dead diptheria bacteria.
 5. The injection would contain some of the poison secreted by the diptheria organisms.
13. A two kilogram roast is removed from the oven, at a temperature of 100°C , and placed immediately in an ice box, where it is cooled to a temperature of 10°C . If the specific heat of the meat is $0.6 \text{ cal/gm/degree}$, and the heat of fusion of the ice in the ice box is 80 cal/gm , and the water from the melting ice is continuously drained off, the number of grams of ice melted in the cooling of the meat would be about:

1. 1080 gms.	4. 1,350 gms.
2. 13.5 gms.	5. 18,000 gms.
3. 180 gms.	
14. Which of the following substances are general antiseptics which destroy bacteria by oxidation, without much damage to surrounding tissues, and may be used on minor cuts?

1. Hydrogen peroxide.	4. Curare.
2. Sodium peroxide.	5. Sodium hypochlorite.
3. Mercuric chloride.	
15. The more effective measures which may be taken to prevent a wooden house from becoming infested with termites, or to remove the termites once becomes infested are:
 1. Painting the surface of all lumber used in the house with creosote.
 2. Preventing the storage of old wooden or paper materials beneath the house.
 3. Burning sulfur beneath the house once a month.
 4. Having the wood injected with orthodichlorbenzene under pressure.
 5. Playing the mating-call of the female termite with a boogie-beat on a clarinet once a week in the basement.

Examination B, Second Examination--Continued

Part Two

Maximum time, fifteen minutes

Below you will find listed a series of materials used for structural purposes, for protectively coating structures, or for the manufacture of smaller objects of a non-metallic nature. Following this is a list of descriptive terms which might apply to them. In each of the forms on your answer sheet bearing the same number as a material, blacken the spaces bearing the same numbers as the descriptive terms which you think apply to that substance. For example, if you think wood hardens by hydration, black in space in form 125.

Answer may be used any number of times, and any question may have any number of answers, or none.

- | | |
|-----------------------|---|
| 121. Portland cement. | 1. Contains large amounts of silicon. |
| 122. Common brick. | 2. Contains large amounts of aluminum silicates. |
| 123. Glass. | 3. Hardens by oxidation and polymerization. |
| 124. China | 4. Hardens by hydration. |
| 125. Wood. | 5. Hardens by evaporation. |
| 126. Earthenware. | 6. Contains large amounts of cellulose. |
| 127. Textstone. | 7. Contains large amounts of cellulose acetate or nitrate. |
| 128. Paint. | 8. Must be heated to a very high temperature in the course of its manufacture. |
| 129. Lacquer. | 9. Contains a resin. |
| 130. Varnish. | 10. Contains an opaque solid like ferric oxide or basic lead carbonate. |
| | 11. Is made from clay and limestone. |
| | 12. Is made from sand, limestone, and sodium carbonate, with other ingredients for special purposes. |
| | 13. Is made by the hitching together of thousands of glucose nuclei, with elimination of water between them, and may be hydrolyzed back to glucose, by a chemical process now used industrially. |
| | 14. May be adapted to a wide variety of totally different uses by small alterations in its composition resulting in major changes in coefficient of thermal expansion, index of refraction, or color. |
| | 15. May be manufactured by turning on a wheel or by pouring into an absorbent mold, cold, before baking. |

Part Three

Maximum time, twenty minutes

Gordon Esterhazy, has discovered many interesting things about the fuel systems in his home since he began taking care of it himself. Among the surprising facts which he has noticed are:

Examination B, Second Examination--Continued

136. The new steam radiators in the Jade room have a much smaller capacity in pounds of water per hour than the old hot-water heaters that used to be there, but keep the room just as warm. The water runs into the radiators at the boiling point. The water which runs out of them is the same temperature it used to be.
137. In the time it takes to heat a saucepan half-full of water, in which the water weighs about as much as the metal, to boiling, you could heat an empty saucepan so hot as to ruin it completely over the same size gas flame.
138. When Mr. Esterhazy poured some drano into cold water in the sink, after Mrs. Esterhazy had got it stopped up, he found the water got very hot.
139. The coils on top of the refrigerator into which the refrigerant flows are so hot they burnt his hand the last time he touched them.
140. In the Hobby Workshop up in the attic, he rigged up an apparatus in which he boiled water on an electric hot plate, and used the steam he got from the boiling to run a small turbine-dynamo and generate electric current. The apparatus worked well enough, but he was never able to get as large a current out of the dynamo as he put into the hot plate.

Below you will find listed a series of possible reasons why Mr. Esterhazy found these facts to be as they were. These reasons bear two sets of numbers, (61-75) and (1-15). Some of the reasons suggested are false statements, some are true. Looking at the first set of numbers first, blacken the space marked T in the form bearing the same number on your answer sheet if you believe the statement to be true, and the space marked F if you believe the answer to be false.

Then, no matter how you marked them, assume each statement to be true, and consider whether, in this case, it would be a reason for the facts which Mr. Esterhazy discovered. If you believe that this statement, assumed to be true, would help explain one or more of Mr. Esterhazy's discoveries, blacken the space bearing the same number as the second number of the reason in the form bearing the same number as the discovery (the discoveries being numbered 136-140, above).

For example, suppose there appeared below the following reason, with these numbers:

87-7. A dynamo can never furnish enough electricity to warm a hot plate. This is a false statement. You would therefore blacken space F in form 87. However, if it were true, it would certainly be a good reason to explain part of the facts observed in discovery 140. You would therefore blacken space 7 in form 140.

THE REASONS

- 61-1 The energy obtained from the condensation of steam is of a much more effective kind, for heating a room, than that obtained by cooling hot water.
- 62-2 Chemical energy can be easily converted into heat energy.
- 63-3 The amount of heat required to raise one ounce of any substance one degree centigrade is called a calorie.
- 64-4 Water acts as a very effective inhibitory catalyst in preventing the thermal decomposition of metals.

Examination B, Second Examination--Continued

- 65-5 Even though the energy of the universe is constant, the entropy tends towards a maximum.
- 66-6 Kinetic energy cannot be converted directly to heat energy.
- 67-7 More heat is liberated in condensing a gram of steam without lowering its temperature than in cooling a gram of boiling water to the freezing point.
- 68-8 All chemical reactions either liberate or absorb energy.
- 69-9 Heat cannot be transferred from cold material to hot material without doing additional work.
- 70-10 The reactions of all substances with water result in the liberation of energy.
- 71-11 Electrical energy cannot be converted to heat without the destruction of some of the energy.
- 72-12 Water has a much higher specific heat than most substances.
- 73-13 A vessel containing a liquid cannot be heated above the boiling point of that liquid until the liquid has all boiled away.
- 74-14 If the specific heat of glass is 0.2 measured in our usual units, exactly 1000 calories would be absorbed by a 50 gram beaker which had had ice and water in it, if it were emptied, then quickly dropped into a kettle of boiling water, and allowed to remain there till it reached the boiling point of water.
- 75-15 The condensation of gases liberates a great deal of heat.

EXAMINATION C
FINAL EXAMINATION
Chemistry 134

This examination will be timed. If you finish any part of the test before the maximum time allotted for it, GO ON TO THE NEXT PART. If you have not finished any part of the test when the maximum time allotted for it has elapsed, GO ON TO THE NEXT PART. You may return to the parts you could not finish if you have any time left over from either of the two later parts.

Part One
Maximum time, fifteen minutes

In each of the questions asked or implied below, select those of the possible answers which are correct, and in the form on your answer sheet bearing the same number as the question, blacken the spaces having the same numbers as the answers. Each question may have any number of answers from none to five. Many of the suggested answers are untrue statements, of course.

1. Which of the following substances would you be surprised to discover in a tooth powder?
 1. Soap.
 2. Silver nitrate.
 3. Sugar.
 4. Potassium cyanide.
 5. Calcium carbonate.
2. Silver would probably soon be in use as a lining for food cans except that:
 1. A thicker lining of silver would be needed than is needed with tin.
 2. Silver is naturally so scarce that enough would not be available to line our cans.
 3. America is largely self-sufficient with respect to its tin needs.
 4. The price of silver is artificially maintained at a high level by political influence.
 5. Silver is so active that it would be attacked by acidic foods.
3. If certain of the following facts were true of aluminum, it would be much less suitable for the manufacture of pots and pans:
 1. If there were only half as many aluminum atoms in the world as there are.
 2. If aluminum did not become coated with a film of its own oxide on exposure to air.
 3. If aluminum had thirteen less protons in its nucleus.
 4. If aluminum were less active than copper.
 5. If aluminum lost electrons much more easily than it does.

Examination C, Final Examination--Continued

4. In developing latent fingerprints by the use of silver nitrate with subsequent reduction, the image of the print which appears on the paper consists chiefly of:
 1. Silver chloride.
 2. Metallic silver.
 3. Sodium chloride.
 4. Silver nitrate.
 5. Pyridine.
5. Which of the following facts about a stain may usually be determined by scientific tests?
 1. That the stain is or is not blood.
 2. That the stain is or is not human blood.
 3. That the stain is the blood of a particular person.
 4. That the stain is not the blood of a particular person.
 5. That the stain is the blood of a person of a particular blood group.
6. Charcoal is used in water purification, in order to:
 1. Destroy pathogenic organisms that may be in the water.
 2. Remove most odorous or colored impurities.
 3. Soften the water.
 4. Increase the epsilon potential of the water at the expense of the zeta potential.
 5. Show whether the bacterial content of the water has been reduced.
7. Solutions of which of the following substances might be good antiseptics for a cut hand?
 1. Merthiolate.
 2. Mercuric chloride.
 3. Sodium hypochlorite.
 4. Silicon carbide.
 5. Metaphen.
8. When calcimine is mixed, ready to be applied, which of the following substances would be found in it which would not be found in paints?
 1. Linseed oil.
 2. Water.
 3. Pigment.
 4. Glue.
 5. Calcium phosphide.
9. Among the chief chemical characteristics of ink which cause forgers of documents to be caught are:
 1. Ink pigment consists chiefly of carbon.
 2. The chemical composition of old writing is quite different from that of new writing made with the same kind of common ink.
 3. The metal cations of different kinds of inks are usually different.
 4. Inks which look similar in ordinary light often look different under ultraviolet light.
 5. Fully aged writing made with ordinary fountain-pen ink consists chiefly of aniline dye, while that made with old-fashioned inks consists chiefly of ferric tannate.

Examination C, Final Examination--Continued

10. Among the important results accomplished by the use of aluminum sulfate in water purification are:
 1. The bacterial content of the water is materially decreased.
 2. The turbidity of the water is largely removed.
 3. Any algae in the water reservoir are killed.
 4. The bactericidal effectiveness of the chlorine is greatly enhanced.
 5. The effectiveness of the rapid-sand filters is much enhanced.
11. The septic tank has found much favor as a means of disposal of sewage from rural homes because:
 1. The liquid portions of the sewage can be better controlled in a septic tank than in a cesspool.
 2. The chemicals used in running the septic tank prevent any possibility of bacterial infection.
 3. The gases obtained in the decomposition of the contents of the tank are usually put to economic advantage.
 4. The products of prolonged bacterial action on sewage have little odor and are harmless.
 5. The septic tank may simply be dug into the ground, without any artificial walls to hold the sewage.
12. A 3-kilogram roast is removed from the oven, at a temperature of 100°C and placed immediately in an ice-box, where it is cooled to a temperature of 10°C . If the specific heat of the meat is $0.7 \text{ cal/gm/degree}$, the heat of fusion of the ice is 80 calories/gram , and the water from the melted ice is drained off immediately, the number of grams of ice melted by the heat from the cooling meat will be about:
1. 27,000. 2. 1080. 3. 236. 4. 6313. 5. 2362.
13. Which of the following statements concerning the hardening of cement are true?
 1. Cement hardens chiefly by oxidation and polymerization.
 2. In the hardening of cement quantities of heat large enough to constitute an engineering problem in large structures are released.
 3. The evaporation of water from the cement mix is the chief change involved in its hardening.
 4. In hardening, the cement combines chemically with the water with which it is mixed.
 5. The hardening of cement could be speeded up if it were mixed with an expensive, volatile solvent, like carbon tetrachloride.
14. Under ordinary circumstances, which of the following conditions must exist if a fire is to be started?
 1. A material whose oxidation liberates energy must be present.
 2. The formation of gases must be avoided.
 3. The chemical reactions proceeding must initiate similar reactions in adjacent material.
 4. The kinesis of igneous phlogistation must be accelerated.
 5. The material must be kept just below its kindling temperature.

Examination C, Final Examination--Continued

15. Which of the following are serious defects of lead white, considered as a pigment for the interior of houses?
 1. The unreliability of the very recently developed process by which it is made.
 2. Its exceedingly low covering power.
 3. Its tendency to poison those who apply it.
 4. Its dull, off-white color.
 5. Its tendency to darken if exposed to sulfide fumes over a period of time.
16. When water is softened by the permutite process, which of the following changes occur?
 1. Bicarbonate and other negatively charged ions are removed from the water.
 2. Ions such as calcium and magnesium are replaced by others whose stearates or palmitates are soluble.
 3. Sodium ions are introduced into the water.
 4. The total number of ions in the water is decreased.
 5. The permutite finally becomes exhausted but can be re-generated by treatment with common salt.
17. In the time required to heat an enameled saucepan containing its own weight of water to the boiling point of the water, an empty saucepan of the same kind heated over the same size flame might be ruined. Among the reasons for this are:
 1. A sauce pan cannot be heated much above the boiling point of its contents for very long.
 2. The coefficients of thermal expansion of enamel and metal are not precisely the same.
 3. The specific heat of water is higher than that of most substances.
 4. Enamelware is attacked more rapidly by boiling water than by water at room temperature.
 5. The boiling of water consumes less than 100 calories per gram.
18. Among the reasons why the coils on top of a mechanical refrigerator become very hot are:
 1. The chemical reaction by which the refrigerant is synthesized in the refrigerator liberates energy.
 2. The condensation of gases liberates energy.
 3. Work must be done to transfer heat from a cooler place to a warmer place.
 4. The specific heat of materials stored in an icebox is usually smaller than that of the refrigerant.
 5. Heat removed from foods in an ice box must go somewhere, and cannot remain in the refrigerant if it is to be used again.
19. In which of the following ways does a lacquer differ from a paint?
 1. A lacquer does not contain a pigment.
 2. The drying of a lacquer involves no chemical change.
 3. The drying of a paint involves no chemical change.
 4. The hard film of most lacquer coats is largely cellulose nitrate or acetate.
 5. Laked pigments may be included in lacquers.

Examination C, Final Examination--Continued

20. For which of the following reasons are water purity standards often stated in terms of maximum number of *B. coli* permitted per cc?
1. *B. coli* are the organisms which cause typhoid fever.
 2. The presence of *B. coli* indicates contamination by intestinal discharges.
 3. *B. coli* are the organisms which cause dysentery.
 4. *B. coli* are much easier to find and culture than pathogenic intestinal bacteria.
 5. *B. coli* are the chief cause of undesirable odors in drinking water.

Part Two

Maximum time, twenty minutes

Mr. and Mrs. Smith, a young couple with a good scientific background, and a high priorities rating, are setting up their new home and establishing themselves in the community. In doing so, they choose the following objects, materials, or courses of action:

121. Mrs. Smith chooses pyrex baking dishes for her kitchen.
122. Mrs. Smith chooses a paint with a zinc-white base as a wall finish for her kitchen.
123. Mr. Smith chooses copper plumbing for installation throughout the house.
124. Mr. Smith chooses fire-protection devices made of Wood's metal for the home.
125. Mrs. Smith chooses sterling silver tableware.
126. The Smiths choose a bronze statue for the formal garden by the fish-pond.
127. Mrs. Smith chooses fine china dinner service by Spode.
128. Mrs. Smith chooses Chlorox to help in washing the dishes and dishcloths and keeping the house clean generally.
129. Mr. Smith chooses copper sulfate to help keep the algae out of the fish-pond.
130. The Smiths choose cast-iron balconies to ornament the upper porch.

Below you will find listed a series of chemical facts and principles which might be reasons why the Smiths made the choices above. Some of these reasons are true statements and some are false statements. They bear two sets of numbers, (61-75) and (1-15). Identifying these statements by the first set of numbers (61-75), please blacken the space marked T in the row on your answer sheet bearing the same number as the question, if you believe the statement to be true; and F if you believe the statement to be false.

Then, no matter how you marked each statement, assume every statement to be true and decide whether, if it were true, it would be a reason for one or more of the choices which Mr. and Mrs. Smith made. If you believe it would be such a reason, then identify it by its second number (1-15) and, in the row on your answer sheet bearing the same number as the choice you think it justifies, blacken the space bearing the same number as the reason.

For example, suppose there appeared below the following possible reason, with these numbers:

Examination C, Final Examination--Continued

87-7. Sterling silver is the cheapest of all kinds of tableware. This is a false statement. You would therefore blacken space F in row 87. However, if it were true, it would certainly be a good reason for the choice of sterling silver tableware indicated in question 124. You would therefore blacken space 7 in row 124.

THE REASONS

- 61-1 Materials composed chiefly of mixtures of metal silicates are usually highly resistant to mechanical breakage.
- 62-2 Cupric ions are very toxic to plants.
- 63-3 Glass has a lower specific heat and better thermal conductivity than most metals.
- 64-4 A well-known alloy consisting of 7.5% copper and the remainder another metal below hydrogen in the electromotive series is not attacked by water, acids, or most oxidizing agents, but darkens on contact with many substances containing sulfur.
- 65-5 There are fewer protons in a zinc atom than electrons in the orbits surrounding its nucleus.
- 66-6 Alloys containing many metals, with bismuth as the most abundant one, have very low melting points.
- 67-7 Although most common metals have black or colored sulfides, one metal has a white sulfide.
- 68-8 Compounds containing copper are harmless to animal life.
- 69-9 Materials composed chiefly of mixtures of metal silicates are usually resistant to most kinds of corrosion.
- 70-10 The presence of silicon in the surface of a common metal makes it much more resistant to corrosion than the pure metal.
- 71-11 Metals below hydrogen in the electromotive series cannot react with water containing no oxidizing materials, however long they are exposed to it.
- 72-12 If objects made by a process involving the partial fusion of clay mixtures in a kiln are immersed periodically in solutions of oxidizing agents, their finish will be improved.
- 73-13 The replacement of part of the silicon dioxide used in making certain common material by a borate produces a material similar in appearance but with a much lower coefficient of thermal expansion.
- 74-14 Metals denser than aluminum can react only with strong oxidizing agents.
- 75-15 After a solution of sodium hypochlorite has been used as an oxidizing agent until all its oxidizing power is consumed, only common salt remains dissolved in the solution.

Part Three

Maximum time, fifteen minutes

In each of the following questions asked or implied, select the answer or answers which are correct, and blacken the spaces bearing the same numbers as these answers in the rows on your answer sheet bearing the same numbers as the questions. Do not forget that each question may have several answers, or none. Do not waste too much time on any one question if you cannot answer it; go on to the next one.

- The Director of the City Food Inspection Service has been titrating a sample of vinegar which is suspected of not being of proper strength. He titrates a 10 ml. sample of the vinegar with 0.5N NaOH solution, and finds that 16.6 ml. are needed to reach the end point of phenolphthalein. In view of these data:

1. Twice as much.
2. Half as much.
3. The same.
4. 0.83 ml.
5. $74/40$ as much.

1. The same molarity.
2. Half the molarity.
3. Twice the molarity.
4. 98/60 the molarity.
5. 60/98 the molarity.

1. Contains too much acetic acid to be sold in Melrose.
2. Contains too little acetic acid to be sold in Melrose.
3. Contains the right amount of acetic acid.
4. Could not possibly contain enough acetic acid to react with this much 0.5N NaOH.
5. Could not possibly have been made from cider.

- | | |
|---------------|--------------|
| 1. 107.9 gms. | 4. 32.4 gms. |
| 2. 51 gms. | 5. 75 gms. |
| 3. 170 gms. | |

Examination C, Final Examination--Continued

52. To say that a mole of sodium chloride is 58.45 grams tells us that:
1. A molecule of sodium chloride weighs 58.45 grams.
 2. A molecule of sodium chloride weighs 58.45/16 times as much as an atom of oxygen.
 3. A molecule of sodium chloride weighs 58.45/16 grams.
 4. A liter of molar NaCl solution contains 58.45 grams of NaCl.
 5. Any volume of NaCl solution containing 58.45 grams of NaCl contains as many sodium ions as there are water molecules in 18 grams of water.
53. The percentage of salt in the seasoning is:
1. 11.7. 2. 15. 3. 50. 4. 67.4. 5. 80.

EXAMINATION D
FIRST EXAMINATION
Chemistry 144

This examination will be timed. If you finish any part of the test before the maximum time allotted for it, GO ON TO THE NEXT PART. If you have not finished any part of the test when the maximum time allotted for it has elapsed, GO ON TO THE NEXT PART. You may return to the parts you could not finish if you have any time left over from either of the two later parts.

Part One
Maximum time, sixteen minutes

In each of the questions below, select the answer or answers which are correct, and blacken the spaces bearing the same numbers as these answers in the rows on your answer sheet bearing the same numbers as the questions. Any question may have any number of answers from none to five.

1. Copper is very little used in dairy equipment, because:
 1. It is likely to poison the milk.
 2. It is so active that it rapidly deteriorates.
 3. It catalyzes the oxidation of parts on the cream molecule.
 4. It is below hydrogen in the electromotive series.
 5. It is likely to impart a metallic flavor to milk.
2. Among the reasons why homogenized milk stays homogenized are:
 1. Small droplets rise through a liquid more slowly than large ones of the same density.
 2. Materials which lower the surface tension of the interface between a fat and water tend to be concentrated at that interface.
 3. Fat forms a lyophillic dispersion in water.
 4. The fat particles are stabilized by certain protein constituents in milk.
 5. Surface tension causes large globules to break up spontaneously into smaller ones.
3. Among the important buffers found in milk are:

1. HPC_4^-	4. HCO_3^-
2. HSO_4^-	5. CN^-
3. Cl^-	
4. The reason why more sodium hydroxide must be added to cows milk than to human milk in order to produce the same decrease in acidity are:
 1. The pH of cows milk is much lower.
 2. The pH of cows milk is much higher.
 3. The salt concentration of cows milk is much higher.
 4. Certain ions in cows milk are vigorous proton donors.
 5. Certain ions in human milk are vigorous proton acceptors.

Examination D, First Examination--Continued

5. If milk is adulterated with water, the effect could be most easily and certainly detected in the laboratory by measuring the:
 1. pH.
 2. Freezing point rise.
 3. Freezing point fall.
 4. Hydrolysis.
 5. Per cent of water in the milk.
6. If you were to look at a sample of milk under the microscope, you could probably see:
 1. The lactose.
 2. The casein.
 3. The lactalbumin.
 4. The salts.
 5. The fat.
7. When a sample of milk is treated with ammonium oxalate and then with rennin:
 1. The rate of coagulation is much accelerated due to the presence of additional ammonium ions.
 2. Coagulation is prevented by the removal of the calcium.
 3. The rate of rennin coagulation is more like that of untreated milk than is the rate of rennin coagulation of milk treated with sodium ions.
 4. The oxalate of ion is shown to be high in the lyotropic series.
 5. Coagulation may be induced by adding other cations.
8. The constituents of milk which exert the greatest effect on its freezing point are:
 1. Fat.
 2. Lactose.
 3. Salts.
 4. Casein.
 5. Lactalbumin.
9. When milk is frozen:
 1. Crystals of virtually pure ice are formed.
 2. The crystals' forms have much the same composition as the milk itself.
 3. The liquid portions remaining become more and more concentrated.
 4. The freezing point of the rest of the unfrozen liquid falls continuously.
 5. The crystals formed contain the salts and lactose dissolved in them, but are free of the suspended materials.
10. Sandiness in ice-cream would not occur if:
 1. Lactose were somewhat less soluble than it is.
 2. The lactose crystals became protected by colloid films as soon as formed.
 3. The solubility of lactose decreased with temperature.
 4. A supersaturated solution of lactose formed on cooling.
 5. The freezing process did not result in separation of solute from solvent.
11. If a large funnel were turned upside down, covered at the mouth with a semi-permeable membrane, partially filled with milk, and the mouth inserted beneath the surface of a vessel of pure water so that the level of water was the same level of milk in the stem of the funnel, you would expect to find after a little while that:
 1. The level of liquid in the funnel stem had risen.
 2. The level of liquid in the funnel stem had fallen.
 3. The level of liquid in the funnel stem would be the same

Examination D, First Examination--Continued

- as the level of liquid in a similar funnel of cow's blood similarly prepared at the same time.
4. The level of liquid would be different if the milk had been drawn from a rather sick cow.
 5. The membrane had burst.
12. A material will probably be a good stabilizing agent for a fat-water mixture if:
1. One portion of its molecule is polar, the other non-polar.
 2. The material tended to decrease the surface tension of the fat-water mixture.
 3. The material is very soluble in water, but only slightly so in fats.
 4. The material is very soluble in fats, only slightly so in water.
 5. The material is attracted by fat and water molecules.
13. A lyophillic colloid differs from a lyophobic one in that:
1. There is repulsion between the dispersed and dispersing phases.
 2. The material may set to a gel.
 3. Electrostatics may play a much less important role in its stabilization.
 4. It will be easier to coagulate.
 5. A stabilizing agent is not usually needed to keep the material dispersed.
14. If a one-tenth normal solution of acid has a pH of 3, we may conclude that:
1. The acid is totally ionized.
 2. The acid is a rather weak acid.
 3. 50 ml. of the acid will react with less sodium hydroxide than would 50 ml. of tenth normal Hydrochloric acid.
 4. The ionization constant of the acid is 10^{-8} .
 5. The anion of the acid is a fairly strong base.
15. Homogenized milk often makes a very bad cheese because:
1. Alteration of small particles by reaction with other substances is more rapid than with large particles.
 2. Homogenization converts most of the casein to paracasein.
 3. Hydrolysis of fat particles results in rancid flavors.
 4. Homogenization increases the rate of loss of moisture from the curd.
 5. Homogenization retards the rate of coagulation.

Part Two

Maximum time, seventeen minutes

A liter of buttermilk contains 9 grams of lactic acid. 11.2 gms of dry sodium lactate are added to it, and dissolved.

Below you will find a series of statements bearing two sets of numbers, (1-15) and (91-105). Considering the second set of numbers first, please blacken the space marked T in the row on your answer sheet bearing the same number as the statement, if you believe the statement is true, and the space marked F if you believe the statement is false.

Then, no matter how you marked the statement, assume it to be true. Identifying it by the first set of numbers, (1-15),

Examination D, First Examination--Continued

blacken the space bearing this number in:

- Row 126, if you believe the statement is a reason why the acidity of the mixture will be reduced.
 Row 127, if you believe the statement is a reason why the acidity will be changed very little or not at all.
 Row 128, if you believe the statement is a reason why the acidity will be increased.

Neglect the effect on the acidity of other constituents of the buttermilk, except water. Assume the volume remains constant when dry sodium lactate is added. The following data may be needed to work out portions of the answer:

- K_a for lactic acid is 1.6×10^{-4} .
 Mol. Wt. lactic acid is 90.
 Mol. Wt. sodium lactate is 112.
 Mol. Wt. sodium hydroxide is 40.
 Lactic acid contains one replaceable hydrogen per molecule.
 Log 1.6 is .20.

THE STATEMENTS

- 1-91 Lactic acid is a strong acid.
 2-92 The addition of sodium acetate would make buttermilk more acidic.
 3-93 The lactate ion is a fairly strong acid.
 4-94 The lactate ion is a fairly strong base.
 5-95 Two grams of NaOH would have about the same effect on the pH of the mixture as 11.2 grams of sodium lactate.
 6-96 Sodium lactate forms a colloidal micelle in solution which strongly absorbs hydrogen ions.
 7-97 Most salts are highly ionized in solution.
 8-98 The pH of the solution after adding the lactate would be about 3.8.
 9-99 The pH of the solution before adding the lactate would be about one.
 10-100 The hydrogen ion concentration of the original buttermilk, before adding the lactate would be 1.6×10^{-4}
 11-101 A solution of sodium lactate always contains some lactic acid molecules.
 12-102 Salts of weak acids are slightly ionized.
 13-103 Aqueous solutions of sodium lactate contain no hydrogen ions.
 14-104 Lactic acid-lactate ions mixed constitute a buffer pair.
 15-105 The addition of salts of weak acids to a solution tends to lower the pH of the solution.

Part Three

Maximum time, seventeen minutes

A dairy producer who is about to make a batch of cheese wishes to retain as much of the calcium content as possible in the curd. He is undecided whether to form his curd by acid coagulation with rennin alone at the pH of pure milk.

Below you will find listed a series of facts and principles which may be involved in this producer's decision. They bear two sets of numbers, (1-15) and (61-75). Identifying them by the second set of numbers (61-75) first, classify the statements as true or false by blackening space T on your answer sheet if you believe them to be true, and space F if you believe

Examination D, First Examination--Continued

them to be false. Then, no matter how you marked the statements, assume them to be true, and identifying them by the second set of numbers (1-15), blacken the space in your answer sheet bearing the same number as the statement, in:

- Row 121, if you believe the statement provides a reason why the milk should be coagulated with acid in order to retain calcium in the curd.
- Row 122, if you believe the statement provides a reason why milk should not be coagulated with acid, because of the effect on the calcium content.
- Row 123, if you believe the statement provides a reason why the milk could not be coagulated by hydronium (hydrogen) ions.
- Row 124, if you believe the statement has little or no bearing on any of the above three issues.

THE STATEMENTS

- 1-61 Casein particles in milk are negatively charged.
- 2-62 Casein particles in milk are positively charged.
- 3-63 Calcium ions are negatively charged.
- 4-64 The extra hydronium ions in acidic solutions tend to make particles dispersed in them become positively charged.
- 5-65 Colloidal particles at the isoelectric point do not tend to attract ions appreciably.
- 6-66 Protein particles carrying both positive and negative charges simultaneously cannot be coagulated by cations.
- 7-67 The charges borne by the casein particles in milk play a very minor role in their stabilization.
- 8-68 Ions absorbed on particles may be replaced by other ions of similar charge present in higher concentrations.
- 9-69 The isoelectric point of casein is about 8.7.
- 10-70 At low pH, casein tends to absorb calcium ions more strongly than at high pH.
- 11-71 The particles of casein are suspended in milk by molecular bombardment.
- 12-72 The casein in milk is largely in true solution.
- 13-73 If milk were subjected to electrophoresis, the casein particles would migrate toward the positive pole.
- 14-74 Lowering the pH of a colloidal mixture increases the negative charge of the dispersed particles.
- 15-75 At pH's between its isoelectric point and the neutral point, casein tends to absorb either calcium or hydrogen ions.

EXAMINATION E
SECOND EXAMINATION
Chemistry 144

This examination will be timed. If you have not finished a portion of the examination during the time allotted for it, GO ON TO THE NEXT PART. If you finish a part of the examination before the end of the time allotted, GO ON TO THE NEXT PART. You may return to the parts you have not finished if you have any time left over at the end of the examination.

Part One
Maximum time, fifteen minutes

In each of the items below, blacken the spaces on the answer sheet bearing the same numbers as the answers you believe to be correct in the rows bearing the same numbers as the questions. Any question may have any number of correct answers, from none to five.

1. Oxides of which of the following elements are often present in samples of soil in quantities in excess of 5%:
1. Al. 2. K. 3. Si. 4. Fe. 5. P.
2. Among the important chemical means by which atmospheric nitrogen is fixed industrially are:
 1. The direct oxidation of nitrogen in an electric arc.
 2. The oxidation of ammonia to nitric acid.
 3. The catalytic hydrogenation of nitrogen under pressure.
 4. Heating calcium carbide in nitrogen, followed by hydrolysis.
 5. The reduction of nitric acid to ammonia.
3. Among the trace elements now clearly known to be essential to plants in minute quantities are:
1. Al 2. B. 3. Cl. 4. Mn. 5. K.
4. In the natural nitrogen cycle, nitrogen occurs in the form of nitrates in:
 1. The product of the action of legume root-nodule bacteria on air.
 2. The plant-protein molecule.
 3. The constituents of protein foods excreted in animal urine.
 4. The atmosphere.
 5. The cyanide ion.
5. The two most commonly used inorganic nitrogen compounds in mixed fertilizers are:
 1. $\text{Ca}(\text{CN})_2$.
 2. $(\text{NH}_4)_2\text{SO}_4$.
 3. NH_4NO_3 .
 4. KH_2PO_4 .
 5. NaNO_3 .

Examination E, Second Examination--Continued

6. Among the properties of calcium cyanamide as a fertilizer material are:
 1. It liberates nitrogen in the form of ammonia to the soil.
 2. Its alkalinity makes it a good ingredient for mixed fertilizers containing ammonium salts.
 3. It tends to reduce soil acidity.
 4. It supplies two of the three essential fertilizer elements needed by plants in greatest abundance.
 5. It would increase the availability of phosphorous in a clayey soil.
7. Treble superphosphate differs from ordinary superphosphate in that:
 1. The phosphorus present in triple superphosphate is in a much more available form than in ordinary superphosphate.
 2. Phosphoric acid is used in the manufacture of treble superphosphate, but not in the manufacture of ordinary superphosphate.
 3. Less sulfur is added to the soil by treble superphosphate than by ordinary superphosphate.
 4. Treble superphosphate contains other essential plant nutrients which ordinary superphosphate does not.
 5. The noise made in grinding treble superphosphate is much higher pitched than with ordinary superphosphate.
8. Adding lime to a clayey soil often increases the availability of the phosphorous because:
 1. Calcium ions tend to replace the ions of other metals on the soil micelle.
 2. Lime contains some phosphorous.
 3. Iron and aluminum phosphates are very insoluble.
 4. Lime hastens the disintegration of underlying phosphate rocks.
 5. Tricalcium phosphate is more soluble than monocalcium phosphate.
9. Nitrogen applied to the soil in the form of fertilizers containing ammonium salts is often retained better than nitrogen applied in the form of fertilizers containing nitrates, because:
 1. Nitrates are soluble in water, ammonium salts are not.
 2. Ammonium ions are charged oppositely to the silicate micelles of the soil.
 3. Nitrate ions are charged oppositely to the silicate micelles of the soil.
 4. Ammonium ions tend to be fixed by the iron and aluminum present.
 5. Soil bases tend to increase the solubility of ammonia.
10. A material which lowers the surfacr tension at the kerosene-water interface is added to an oil spray which is about to be applied to some plants. One would expect that:
 1. Smaller droplets of kerosene could be dispersed in the water.
 2. The spray would spread better on the foliage.
 3. The foliage would be more thoroughly wet by the spray.
 4. The freezing point of the spray would be raised.
 5. The kerosene and water would tend to separate more sharply into layers.

Examination E, Second Examination--Continued

11. Due to overly intensive cultivation, much of the organic matter contained in a field has been oxidized, and its nitrogen liberated and washed away to a large extent. In order to remedy this defect, the farmer plows green cornstalks under the field. One would expect that:
 1. The organic matter of the cornstalks would be incorporated into the soil through decay.
 2. The nitrogen content of the field would increase sharply.
 3. The nitrogen content of the field would decrease sharply.
 4. The rate of evolution of CO_2 from the field would increase.
 5. The pH of the soil would rise.
12. A proprietary rodent-killer is put on the market with no statement as to its active ingredients on the label. It is desired to test it for arsenic. This might be done by:
 1. Acidifying with HCl , adding a few drops of FeCl_3 , and boiling with copper discs.
 2. Adding NH_4OH and watching for a deep blue coloration.
 3. Acidifying with HNO_3 , adding BaCl_2 solution, and watching for a white precipitate.
 4. Making barely acid with HCl , and adding hydrogen sulfide solution, looking for a yellow precipitate.
 5. Adding FeSO_4 solution, and pouring concentrated H_2SO_4 slantwise beneath the mixture.
13. A fertilizer is described as being of grade 3-12-6. Assuming that all the nitrogen present is in the form of NaNO_3 , all the phosphorus in the form of CaHPO_4 , and all the potassium as KCl , and using the periodic table for our atomic weights, we may conclude that the weight of NaNO_3 present in 100 grams of the fertilizer is about:
 1. 3 gms. 2. 15 gms. 3. 18 gms. 4. 30 gms. 5. 36 gms.
14. In this same fertilizer, the weight of CaHPO_4 present in 100 grams would be about:
 1. 6 gms. 2. 15 gms. 3. 23 gms. 4. 142 gms. 5. 136 gms.
15. In this same fertilizer the weight of KCl present would be about:
 1. 6 gms. 2. 10 gms. 3. 20 gms. 4. 94 gms. 5. 100 gms.

Part Two

Maximum time, twenty minutes.

Below you will find described a series of agricultural situations, which are numbered 121-130. Each of these situations illustrates some chemical principle or principles which are stated immediately following, and which are numbered 1-15. Each principle may be used as many times as applicable, and each situation may illustrate any number of principles. All the principles are true statements.

In the row on your answer sheet bearing the same number as the situation described, blacken the space on the answer sheet bearing the same number as the principles which you think the situation illustrates.

Examination E, Second Examination--ContinuedTHE SITUATIONS:

121. When a powdered mixed fertilizer containing potassium nitrate, calcium phosphate, and ammonium sulfate was applied to a field, the responses of various rows to it were found to differ. This resulted from some separation of the ingredients in storage and transit, so that applications of the fertilizer were not uniform.
122. A farmer mixes himself a fertilizer from chemicals which he had bought commercially, among which was the deliquescent salt, ammonium acid phosphite. When he sought to apply the mixture, he found that it has become sticky and had caked in the container.
123. The Ludgate family have been farming the same field since about 1829, using the fertilizers common at that time regularly, and adopting a reasonably varied cropping program. Within the past several decades, it has become necessary to add increasing quantities of lime as well as fertilizer to the soil.
124. One of the fields which the Lamont family farms has shown a marked tendency toward acidity lately, and cattle fed on grains grown on it tend to develop a craving for bones. The county agent recommends treating the field with basic slag.
125. Mr. Ludgate, having been told by the county agent that certain deficiencies in his potato crop were due to lack of potassium in the soil applied a commercial fertilizer especially rich in potassium chloride to the roots of the plants. The potatoes shriveled up and died.
126. Another of the Lamont family fields shows a marked acidity, and all plants except legumes grown on it turn out stunted, even if lime is applied to the portion of the field where they are planted. It has been decided to use calcium cyanamide on this field, instead of the ammonium sulfate which had applied to other portions of the farm previously.
127. The Ludgates have a field adjacent to the Lamont field described in 126 above, with identical characteristics. The Ludgates decided to treat this field with an incomplete fertilizer which they mixed together from lime and ammonium sulfate, and kept for some months until ready to apply it. Everything in the field turned out almost as stunted as usual.
128. Much of the garden truck grown on the Ludgate farm appears to be slightly stunted and yellowed, although the gardens are well cultivated, and fertilized with the best grades of synthetic inorganic fertilizers, containing $(\text{NH}_4)_2\text{SO}_4$. The county agent suggests that this may be due to a deficiency of magnesium.
129. The Lamonts have been in the habit of using fertilizers containing large quantities of sodium nitrate on their fields in the past. This year, however, they were obliged to accept a mixture containing dried blood, milorganite, and other organic fertilizer materials instead.
130. In Nebraska are three tracts of land, side by side. The first has never been plowed. The second has been subjected to grain farming for some years, without fertilization, but

Examination E, Second Examination--Continued

with the return of the manure of all animals fed on grain grown from it. The third has been similarly farmed, and the manure has also been returned to it, but commercial fertilizers have also been liberally applied. The proportion of plant nutrients in the first and last fields are about the same, but in the second it is very much lower.

THE PRINCIPLES

1. Ammonium salts tend to lower the pH of soil much more than the organic fertilizers in wide use before the first world war.
2. Many of the ingredients of inorganic fertilizers are very soluble and highly ionized in water.
3. Some substances attract sufficient water from the atmosphere to dissolve them.
4. Inorganic fertilizers tend to consist of rather simple mixtures of quite pure substances.
5. The ammonium ion is a fairly vigorous proton donor.
6. $\text{CaCN}_2 + 3\text{H}_2\text{O} \rightarrow \text{CaCO}_3 + 2\text{NH}_3$.
7. Salts of the elements in group one of the periodic chart are usually very soluble.
8. The specific gravities of the different substances used in a mixed fertilizer are often very different.
9. Living organisms contain only atoms derived from soil or air, and return only small numbers of these atoms during their lives.
10. The osmotic pressures of solutions is much higher than that of pure solvents.
11. Factories which fix nitrogen for use in fertilizers can also fix nitrogen for use in explosives.
12. The reaction of ammonia with carbon dioxide produces a pure crystalline substance of great value in fertilizers.
13. Strong bases drive weaker ones from their salts.
14. A certain alkaline by-product of the steel industry is a good source of phosphorus in the soil.
15. Hydrogen ions tend to replace other more essential cations on the soil micelle.

Part Three

Maximum time, fifteen minutes

Below you will find listed a series of substances, numbered from 131-140. Following this list of substances you will find a series of descriptive terms, numbered from 1-15. If you think that any one of these descriptive terms applies to any of the substances listed, blacken the space bearing the same number as the descriptive term in the row bearing the same number as the substance. Any substance may be described by any number of terms, and any descriptive term may be applied to any number of substances.

Examination E, Second Examination--ContinuedTHE SUBSTANCES

- 131. Bordeaux mixture.
- 132. Lime-sulfur.
- 133. Dreft.
- 134. Paris green.
- 135. Sapamines.
- 136. Sodium fluoride.
- 137. Calcium arsenate.
- 138. Igeypons.
- 139. Hydrogen cyanide.
- 140. Semesan-Bel.

DESCRIPTIVE TERMS

- 1. Is used as an insecticide.
- 2. Is used as a fungicide.
- 3. Is used as a fumigant.
- 4. Is used as a wetting agent.
- 5. Contains arsenic.
- 6. Could not perform its function if it did not form long ions with polar heads and non-polar tails.
- 7. Contains copper.
- 8. Contains mercury, attacked to complex organic radical.
- 9. Although extremely poisonous to animals, this contains three chemical elements found in all muscular tissue in abundance, and no other.
- 10. Differs from other other substances which perform the same function, in that its detergent action derives from the cation rather than the anion.
- 11. This generates some hydrogen sulfide in the reaction by which it kills organisms.
- 12. Too soluble to use on foliage, this is a common, though fairly toxic ingredient of ant and roach powders.
- 13. Made by mixing together lime and a metallic sulfate in water.
- 14. The effectiveness of this seems to depend on the concentration of polysulfide ions in it.
- 15. Unlike soap, this could be used to stabilize Bordeaux mixture.

EZF/wlk/dk
144x
100 copies
3/26/43

EXAMINATION F
FINAL EXAMINATION
Chemistry 144

This examination will be timed. If you finish any part of the test before the maximum time allotted for it, GO ON TO THE NEXT PART. If you have not finished any part of the test when the time allotted for it has expired, GO ON TO THE NEXT PART. If you have any time left over after finishing the last part you may return to any unfinished portions of the examination.

Part One
Maximum time, fifteen minutes

In each of the questions below, select the answer or answers which are correct, and blacken the spaces corresponding to these answers on your answer sheet. Any question may have any number of answers from none to five.

1. Aluminum would probably be much less suitable for use in kitchenware if:
 1. Aluminum had 13 fewer protons in its nucleus than it has.
 2. Aluminum were a less active metal than it is.
 3. Exposed aluminum surfaces did not become coated with Al_2O_3 .
 4. There were only two-thirds as many aluminum atoms in the earth as there are.
 5. Aluminum could be prepared by electrolysis of fused aluminum salts.
2. If milk were adulterated with water, the effect could be most certainly detected by observing:
 1. The hydrolysis.
 2. The Brownian movement.
 3. The pH.
 4. The freezing point rise.
 5. The per cent of water in the milk.
3. The use of lead pipe in plumbing installations has gradually been abandoned because:
 1. Lead is below hydrogen in the electromotive series.
 2. Lead is slightly above hydrogen in the electromotive series.
 3. All available lead is needed in the war effort for the manufacture of lead pipe cinches.
 4. Soluble lead salts are very poisonous.
 5. Lead is too brittle to be worked easily.
4. Case hardening of steel is a process whereby:
 1. Steel is heated to a high temperature and then plunged into warm oil to increase its toughness.
 2. Steel is very slowly cooled from red heat to room temperature in a hermetically sealed case.
 3. Steel is buried while hot in sawdust or other carbonaceous materials to make the surface very hard.

Examination F, Final Examination--Continued

4. The resistance of the steel to rusting is increased at the expense of surface hardness.
5. The carbon content of the surface is raised, thus giving resistance to abrasion without brittleness.
5. Homogenized milk stays homogenized because:
 1. Small droplets rise through a liquid more slowly than large ones of the same.
 2. Fat forms a lyophillic dispersion in water.
 3. The fat particles are stabilized by protein constituents of milk.
 4. Lactose exhibits a considerable detergent action in milk.
 5. Particles which lower the surface tension at an oil-water interface tend to be concentrated there.
6. Ice cream would probably not become sandy if:
 1. Freezing a solution did not force the solute from it.
 2. The solubility of lactose decreased with temperature decrease.
 3. Lactose were much more soluble than it is.
 4. A protective colloid were added to the ice-cream mix.
 5. The ice-cream mix were not very viscous when it is frozen.
7. Among the properties of calcium cyanamide used as a fertilizer material are:
 1. Its alkalinity makes it a good ingredient to include in mixed fertilizers containing ammonium salts.
 2. It liberates nitrogen in the form of ammonia to the soil.
 3. It would increase the availability of phosphorous in a clayey soil.
 4. It supplies two of the three soil elements needed by plants in greatest abundance.
 5. It lowers the pH of the soil.
8. The typical fertilizer mixture on the market in 1940 differed from the typical fertilizer mixture of 1900 in that the 1940 mixture:
 1. Tended to make the soil more alkaline.
 2. Usually contained purer substances as components of the mixture.
 3. Contained larger amounts of the trace elements.
 4. Contained potassium salts free of magnesium.
 5. Contained more hygroscopic materials.
9. The addition of sodium lactate solution to a very sour buttermilk would make the buttermilk much less sour. Among the reasons for this are:
 1. The lactate ion is a fairly strong base.
 2. Colloidal sodium lactate tends to absorb hydrogen ions.
 3. The addition of salts of weak acids to solutions of the acids tends to lower the pH of the acids.
 4. Lactate ions in water solution exist in equilibrium with undissociated lactic acid molecules.
 5. Salts of weak acids are strong electrolytes.
10. Pyrex glass differs from ordinary glass in:
 1. The inclusion of rather large amounts of PbO in the batch.
 2. Its low coefficient of thermal expansion.
 3. Its low index of refraction.

Examination F, Final Examination--Continued

4. The substitution borate for some of the silicate of ordinary glass.
5. Its high content of Na_2CO_3 .
11. Scientific tests make it possible in most cases to determine which of the following facts about a stain suspected of being blood?
 1. That the stain is or is not blood.
 2. That the stain is or is not human blood.
 3. That the stain is the blood of a person of a particular race.
 4. That the stain is not the blood of a particular person.
 5. That the stain is the blood of a particular person.
12. The tendency of many modern fertilizers to decrease the magnesium content of soils to which they are applied may be explained by:
 1. The fact that they often contain large amounts of $(\text{NH}_4)_2\text{SO}_4$.
 2. The fact that they often contain dolomite.
 3. The fact that high-grade rather than low-grade potassium salts are now used.
 4. The fact that iron and phosphorous tend to bind magnesium found in the soil.
 5. The fact that hydrogen ions tend to replace others on the soil micelle.
13. Aluminum sulfate used in water purification is helpful in:
 1. Removing many bacteria from the water.
 2. Killing any algae present in the reservoir.
 3. Increasing the bactericidal effectiveness of the chlorine.
 4. Removing the turbidity from the water.
 5. Making the rapid sand filters effective.
14. A material which is to act as an industrial or military explosive will possess which of the following characteristics:
 1. A great deal of energy must be liberated in making it.
 2. Some of its decomposition products must be gases.
 3. It must have a fairly low critical temperature.
 4. Its decomposition products must be highly unstable.
 5. It usually contains nitrogen.
15. Sodium thiosulfate is used by photographers chiefly to:
 1. Prepare a sensitized film to receive the photograph.
 2. Reduce the exposed silver bromide particles and thus develop the picture.
 3. Dissolve the undeveloped portions of the emulsion to prevent subsequent "fading."
 4. Prevent the gelatin of the film from being softened in the fixing bath.
 5. Convert the silver bromide particles in the film to metallic silver.
16. A photographic negative comes from the developing bath much too dark to be satisfactory. This might have resulted from:
 1. Allowing too little light to reach the film when the picture was taken.
 2. Using too warm a solution of developer.
 3. Leaving the film in the developer too long.

Examination F, Final Examination--Continued

4. Using a developing solution with an insufficient reducing potential.
 5. Using too large a diaphragm opening and too slow a shutter speed.
17. Among the reasons why an ordinary incendiary bomb cannot be extinguished with water are:
1. Aluminum is capable of reducing iron oxide directly.
 2. Thermite mixture liberates incandescent vapors of aluminum oxide when wet.
 3. Magnesium is far above hydrogen in the electromotive series.
 4. The reaction heats water above its kindling temperature.
 5. The hydrogen liberated by the action of the bomb shell on water is inflammable.
18. A typical gas mask canister contains ingredients designed for:
1. Dephlogistication.
 2. Oxidation.
 3. Reduction.
 4. Absorption.
 5. Neutralization.
19. Silver would probably be used to line food cans in America except that:
1. Silver is too active a metal for this use.
 2. The United States is nearly self-sufficient with respect to her tin needs.
 3. Silver is too rare and expensive for such a purpose.
 4. The price of silver is artificially maintained by political influence.
 5. A much thicker coating of silver than of tin would be needed for this purpose.
20. It would be impossible to boil water, use the steam to run a turbine and make electricity, and use the electricity to boil the water for the turbine because:
1. Chemical energy cannot be transformed into electrical energy.
 2. The total amount of energy which can be derived from a system is always less than the total amount put in.
 3. Even though the energy of the world is constant, the entropy tends toward a maximum.
 4. The heat of vaporization of water is greater than the mechanical equivalent of heat in joules.
 5. Exactly as much energy is dissipated in a system through all channels as is put into it.

Part Two

Maximum time, twenty minutes

Mr. and Mrs. Smith, a young couple with a good scientific background, and a high priorities rating, are setting up their new home and establishing themselves in the community. In doing so, they make the following choices:

121. Pyrex baking dishes for her kitchen.

Examination F, Final Examination--Continued

122. A paint with a zinc-white base as a wall finish for her kitchen.
123. Copper plumbing for installation throughout the house.
124. Fire-protection devices made of Wood's metal for the home.
125. Sterling silver tableware.
126. A bronze statue for the formal garden by the fish-pond.
127. Fine china dinner service by Spode.
128. Chlorox to help in washing the dishes and dishcloths and keeping the house clean generally.
129. Copper sulfate to help keep the algae out of the fish-pond.
130. Cast-iron balconies to ornament the upper porch.

Below you will find listed a series of chemical facts and principles which might be reasons why the Smiths made the choices above. Some of these reasons are true statements, some are false statements, bearing two sets of numbers, (61-75) and (1-15).

Identifying these statements by the first set of numbers (61-75), please blacken the space marked T in the row on your answer sheet bearing the same number as the question, if you believe the statement to be true; and F if you believe the statement to be false.

Then, no matter how you marked each statement, assume every statement to be true and decide whether, if it were true, it would be a reason for one or more of the choices which Mr. and Mrs. Smith made. If you believe it would be such a reason, then identify it by its second number (1-15) and, in the row on your answer sheet bearing the same number as the choice you think it justifies, blacken the space bearing the same number as the reason.

For example, suppose there appeared below the following possible reason, with these numbers:

87-7. Sterling silver is the cheapest of all kinds of tableware. This is a false statement. You would therefore blacken space F in row 87. However, if it were true, it would certainly be a good reason for the choice of sterling silver tableware indicated in question 125. You would therefore blacken space 7 in row 125.

THE REASONS

- 61-1. Materials composed chiefly of mixtures of metal silicates are usually highly resistant to mechanical breakage.
- 62-2. Cupric ions are very toxic to plants.
- 63-3. Glass has a lower specific heat and better thermal conductivity than most metals.
- 64-4. A well-known alloy consisting of 7.5 per cent copper and the remainder another metal below hydrogen in the electro-motive series is not attacked by water, acids, or most oxidizing agents, but darkens on contact with many substances containing sulfur.
- 65-5. There are fewer protons in a zinc atom than electrons in the orbits surrounding its nucleus.
- 66-6. Alloys containing many metals, with bismuth as the most abundant one, have very low melting points.
- 67-7. Although most common metals have black or colored sulfides, one metal has a white sulfide.
- 68-8. Compounds containing copper are harmless to animal life.
- 69-9. Materials composed chiefly of mixtures of metal silicates are usually resistant to most kinds of corrosion.

Examination F, Final Examination--Continued

- 70-10. The presence of silicon in the surface of a common metal makes it much more resistant to corrosion than the pure metal.
- 71-11. Metals below hydrogen in the electromotive series cannot react with water containing no oxidizing materials, however long they are exposed to it.
- 72-12. If objects made by a process involving the partial fusion of clay mixtures in a kiln are immersed periodically in solutions of oxidizing agents, their finish will be improved.
- 73-13. The replacement of part of the silicon dioxide used in making certain common material by a borate produces a material similar in appearance but with a much lower coefficient of thermal expansion.
- 74-14. Metals denser than aluminum can react only with strong oxidizing agents.
- 75-15. After a solution of sodium hypochlorite has been used as an oxidizing agent until all its oxidizing power is consumed it contributes only common salt to the solution.

Part Three

Maximum time, fifteen minutes

Below you will find listed a series of substances numbered 131-140. Following this will be a list of fifteen possible characteristics which each of these substances might possess. In the row on your answer sheet bearing the same number as the substance, blacken the spaces bearing the same numbers as the characteristics which the substance possesses. Each substance may possess any number of characteristics, and each characteristic may apply to any number of substances:

THE SUBSTANCES	THE CHARACTERISTICS
131. Bordeaux mixture.	1. Is used as a fungicide.
132. Lime-sulfur	2. Is used as an insecticide.
133. Paris green.	3. Suitable for use as a fumigant, but not dense enough for military use.
134. Lewisite.	4. Contains arsenic.
135. Sodium fluoride.	5. Is a vesicant.
136. Calcium arsenate.	6. A highly toxic true gas at ordinary temperatures.
137. Phosgene.	7. Is a powerful explosive.
138. Hydrogen cyanide.	8. Contains copper.
139. Tetryl.	9. One of the first synthetic chemicals used to destroy specific disease organisms.
140. Salvarsan.	10. This generates some H_2S in the reaction by which it kills organisms.
	11. Too soluble to use on foliage, this is a common, though fairly toxic ingredient of household ant and roach powders.
	12. Made by mixing together lime and a metallic sulfate in water.
	13. Finds its chief military use as a lachrymat ^{or} .

Examination F, Final Examination--Continued

14. Kills through delayed action, primarily by releasing HCl in the respiratory organs of the organisms affected.
15. Although not used as an insecticide, or fungicide, this would be far less useful if it did not adhere to foliage for some weeks after application.

INITIAL STATEMENT CONCERNING PROCEDURES IN
CHEMISTRY 134, AND BIBLIOGRAPHY

Please read this document with special care.

In order to do best the job which we are to do together--the job of using the chemistry course to help you to become the happiest and most effective people which you can become--we must, of course, agree on certain procedures to be followed. These procedures are tentative, and may be altered at any time if we can think of better ones. Until we do, however, we will assume that those described below are in effect, and that we will all follow them. They arise from the experience of the exploratory section which developed the method last year:

1. Since we do not use a textbook, we will not, obviously, follow the procedure to which you may have been subjected in high school, of reading page assignments for each class period. Instead, you will be responsible for developing your own program of reading from the library sources, especially from the reserve collection especially assembled for you and available on three-day loan. From time to time, certain important portions of this bibliographic material will be set aside as required, but day-by-day assignments will not be made.
2. Your readings will serve two purposes: First, to provide you with an adequate background to allow you to understand and contribute to the discussions of various problems in various areas of need, as will have been explained in class meeting; and second, to provide you with enough information to permit you to write a detailed and profound report on the applications of chemistry to the particular problem you select.
3. In order to allow a continuous record to be kept of the scope and depth of your reading, each of us will hand in reading cards, giving the following information about each selection you read:
 - a. Author, and title.
 - b. Pages or chapters read.
 - c. A concise statement of the principle facts contained in the material, or of its chief thesis, if it is not a factual study.
 - d. Your personal evaluation of the material--whether you think it helpful for your particular problem, whether you think it well-written, easily understood. In short, your reaction to it.

These cards will be due every two weeks, at the Friday meeting of the lecture section, beginning Friday, October 2nd. If you have done no reading during the two weeks, which may be true under certain exceptional circumstances,

be sure to hand in a card stating that this is the case, so that your file can be kept up to date. Cards, size 8x5, must be used, as this is the size of the file.

4. One of your most important activities in the course will be the preparation of intensive reports on problems in each area of need; reports, that is, on the relationship of chemical facts and principles to the problem. Each of you will prepare seven or eight such reports in the course of the year--about one each month after we are well started. The procedure for these will be as follows:
 - a. The instructor will prepare as soon as possible a list of sample topics in each area, and a list of dates upon which a report on this topic would be acceptable. You will select a topic, or think of a new one within the area, and choose one of the dates as a time by which the report can be finished, and return your copy of the list, indicating your choice, to the instructor.
 - b. You will then be furnished, either in a conference, or in a written bulletin, with an analysis of some of the chemical facts and principles which might be represented in the problem report, and a beginning list of references. These are not intended to be exhaustive, and will serve only to get you started. You will then proceed by intelligent use of your own library skills.
 - c. On the date chosen, you will submit your report. It should be well integrated, that is, it should fit together well, and should be concerned primarily with the applications of chemistry to your problem, not merely with the problem itself.
 - d. When the topic on which you have chosen to report comes up for discussion during lecture period, you and others who have chosen the topic will be expected to take a particularly active part in discussions, and to assist the instructor in bringing out any important points which you feel have not been made sufficiently clear.

The Laboratory

Special laboratory experiments closely related to the problems with which you are to deal are being developed. Each student is expected to work out these experiments individually, unless special co-operative methods are followed in particular experiments. A brief report on the experiment will be made, the nature of which will be made clear in the mimeographed directions for laboratory to be supplied you.

Bibliography

A special collection of books has been assembled for your use in the reserve room of the library. These books are now available on three-day loan. Everybody will not, of course, be expected to read every book, but it is on these books that you will

draw for materials for your problems and background reading--they will be your chief learning resource. Please do not keep them out longer than you have to. If you begin to find it difficult to get books, be sure to complain to the instructor immediately, so that new copies may be sought, or the books placed on straight reserve.

While we will not be using all the books all the time, you will do well to read ahead of yourself where possible, so that you can use the book when there is less demand for it. Also, be sure to explore the library as fully as possible so that you can find and use additional materials, and special library devices, such as the card catalogue and chem. abstracts.

At present, the following books have been requested for the collection:

1. Eastman Kodak Co., Elementary Photographic Chemistry.
2. Holmes, Out of the Test Tube.
3. Rhodes, Forensic Chemistry.
4. Shohl, Mineral Metabolism.
5. Bernal, The Social Function of Science.
6. Berth, Christy, Pioneers of Plenty. (Farm chemurgy movement.)
7. Martin, Hubert. Scientific Principles of Plant Protection.
8. Cameron, Chemistry in Relation to Fire Risk and Fire Prevention.
9. Prentiss, Chemicals in War.
10. _____. Forensic Chemistry and Scientific Criminal Investigation.
11. Rogers, C.H., Textbook of Inorganic Pharmaceutical Chemistry.
12. Sadtler, Chemistry of Familiar Things.
13. U.S.D.A. Yearbook. Soils and Man.
14. Rogers' Associates. Fundamentals of Dairy Science.
15. Riegel. Industrial Chemistry.
16. Gortner. Selected Topics in Colloid Chemistry.
17. Thomas. Colloid Chemistry.
18. Ahrens and others. Living Chemistry.
19. Haynes and Hauser. Rationed Rubber and What to do About It.
20. _____. Applied Paint and Varnish Chemistry for the Chemist and Layman.
21. Rice. Electronic Structure and Chemical Binding.
22. Lange. Handbook of Chemistry.
23. Buswell, The Chemistry of Water and Sewage Treatment.
24. J. D. Betz and Co. Water Handbook.
25. Shepherd. The Chemistry and Toxicology of Insecticides.
26. Partington. A Textbook of Inorganic Chemistry.

SELECTION SHEET AND DETAILED REFERENCES FOR
PROBLEM TOPICS IN AREA ONE

The Contribution of Chemistry to Needs Arising From
Private Consumption

This sheet is supplementary to the sheet on procedures and bibliography handed out to laboratory groups beginning Wednesday, September 16th. The works referred to herein by the authors' names may be identified by referring to this sheet. Only those books are included in this present document which were actually in the library, on our special shelves, at 8:00 P.M. September 16th. Additions are being made rapidly.

Background Material

For those of you who would like to get a background of fundamental chemical theory as soon as possible, to avoid any feeling of confusion arising in the course of your later readings or discussions, the following references are recommended. While you are not required to read them at the outset of the course, you will find it easier to do so than to attempt to find in the materials discussions of each principle separately as it arises, and will find an understanding of our discussions much easier for you. It is strongly recommended, therefore, that everyone read most of the following reference materials:

Holmes, chapters 1-5, 11.
Ahrens, units 1-10.
Sadtler, chapters 1, 3.

Those of you who wish to pursue the theoretical background more deeply will find the following works helpful:

Rice, chapters 1-5, 7, 8.
Partington, chapters 1, 2, 5-9, 14, 15, 24, 25.

Problem Topics--Area One

1. How can chemistry help me to choose suitable metalware for the plumbing system of my home, kitchen utensils, and other exposed metallic devices?

Holmes, chapters 1-5, 11 (background only), 33 (the light metals).
Ahrens, units 4 (background), 21 (chemistry of cooking utensils), 22 (tableware).
Sadtler, chapters 1, 3 (background), 9 (metals), page 328 (metallurgy).
Partington, chapters 24, 25 (background), 38, 42, 44-47, 49, 50 (various metals).
Riegel, chapter 49.

2. How can chemistry help me to choose and care for window glass in my home?
 Holmes, chapter 28.
 Sadtler, chapters 8 (alkalies and salts), 21.
 Ahrens, pages 342-45, 355-56.
 Partington, chapter 36 (silicon and boron only).
 Riegel, chapter 11.
 Rice, chapters 12, 16-18 (crystal structures only--rather abstruse).
3. How can chemistry assist me to choose suitable paints, varnishes, or lacquers to finish and protect the home and its contents?
 Ahrens, unit 27.
 Sadtler, chapter 28.
 Riegel, chapter 31.
 Partington, (look up individual pigment compounds in index).
4. How can chemistry assist me in choosing china, earthenware, and enameled articles for use in the home?
 Ahrens, unit 22.
 Riegel, chapter 10.
 Partington, pages 883-86.
5. How can chemistry assist me to choose and use wisely a fuel system for heating the home?
 Holmes, chapters 3, 19.
 Ahrens, units 3, 23.
 Sadtler, chapters 5, 6.
 Riegel, chapters 12, 16.
6. How can chemistry help me to choose a suitable structural material for my home?
 Holmes, chapter 34.
 Ahrens, unit 26.
 Riegel, chapters 9, 47, 48.
7. How can chemistry help me to choose effective and safe antiseptics, germicides, and disinfectants?
 Holmes, chapter 25 (medicines and anesthetics in general--not too well adapted).
 Ahrens, unit 15.
 Partington, (chemical properties of individual compounds).
8. How can chemistry help me to choose dentifrices, shaving soaps, and other aids to an attractive personal appearance?
 Ahrens, unit 16.
 Riegel, chapter 32.
9. How can chemistry help me to use my refrigerator most effectively?
 Ahrens, unit 24.
 Sadtler, chapters 5, 6.
 Riegel, chapter 12.
 Partington, chapters 5, 15; pages 138-45.

Selection Contract

Student copy.--Please encircle the appropriate numbers and dates.

I undertake to submit a report on topic 1 2 3 4 5 6 7 8 9, or one especially approved by the instructor and listed on the back of this form, by October 21st, 23rd, 28th.

-----Tear here-----Tear here-----

Instructor's copy.--To be turned in by Friday, September 25th. Please encircle appropriate numbers and dates.

I undertake to report on topic 1 2 3 4 5 6 7 8 9, or the topic named on back and approved by the instructor, by October 21st, 23rd, 28th.

Signed _____

AREA ONE--PROBLEM 3

How can chemistry help me in devising decorative and protective coatings for the interiors of my house, its exteriors, my automobile, my farm buildings, and other objects?

I. What is the purpose of a surface finish?

- A. To protect the structural material which it covers from attack by various chemical agents with which it comes in contact, such as water, oxygen, and other atmospheric constituents.
- B. To provide a surface for the structural material from which disfiguring and otherwise obnoxious materials which do not themselves attack the structural material, may be removed more easily than they could be from the surface of the structural material itself.
- C. To provide a more beautiful surface than that which would be presented by an ordinary structural surface.

II. A. What are some of the changes which may be brought about in structural materials, against which surface coatings are a protection?

1. Metals.

- a. Rusting. Kinetics of rusting. Reactions between metal and water vapor to form H_2 and metal oxides. Restriction of rusting to metals which are above hydrogen in the electromotive series, and whose oxides the inevitable product of rusting, do not adhere to the surface of the metal. Iron as an example of such a metal.
- b. Tarnishing. Reactions of metal with sulfide fumes. Analogous to rusting in thio-series of compounds. Chiefly of aesthetic interest, due to adhesive qualities of most metal sulfides.

2. Woods.

- a. Weathering. Water as a catalyst in various types of decompositions. Effects of weathering on the wood structure. Surface area as a factor in affecting reaction rates--the law of mass action. Spongy texture of untreated wood surfaces

B. What are some of the characteristics which a finish must have if it is to be freed of obnoxious materials which adhere to it?

- 1. Smoothness. Minimum of surface area in which particles may lodge.
- 2. Chemical inertness toward such materials as soap, water, and other solvents which might be used to clean it. Among the changes which might be brought about by such materials, and which the coating must

prevent are:

- a. Softening due to effect of water on colloidal structure. Difficulty of water on wallpaper, very alkaline cleaning materials on woods.
 - b. Solution, in the solvent which is used to dissolve the cleaning agent and to loosen the dirt.
 - c. Attack due to alkaline or acid nature of the medium. Alkaline nature of most soap solutions and trisodium phosphate cleansers. Greater effectiveness of alkaline solutions in cleaning most greasy surfaces.
 - d. Abrasion. Mechanical removal of material in the cleaning process. Much intensified in ordinary wear between moving surfaces.
- C. What characteristics in a surface are usually felt to give it beauty?
1. Lustre--usually restrained.
 2. Color and pattern.
- D. Certain special characteristics needed for special surfaces. Ability or inability to be wet by certain solvents, ability to absorb light, etc.

III. What are some of the agents used to produce these surface effects, what kinds of surfaces do they produce, and what are their characteristics as chemicals?

- A. Paints suspended in water, stabilized by animal colloid such as casine or glue, and consisting of a white covering agent, with or without added water soluble dyes.
1. Calcimines. CaSO_4 pigment, with or without color.
 2. Whitewash. $\text{Ca}(\text{OH})_2$ suspension, converted to CaCO_3 by atmosphere on painted structure.

These are characteristically inexpensive, dull, form discontinuous surface affording fairly little protection against action of water or atmosphere. May be used on interiors; whitewash may be used on exteriors but does not last long. Cost of labor relatively high. Highly susceptible to abrasion.

- B. Paints suspended in oils which polymerize to yield solid, continuous surface, formed partially through oxidation, but in which evaporation of the solvent (or thinner) plays comparatively little part. Opacity and color given by presence of solid, colloiddally suspended materials, usually inorganic, known as pigments. Possess fairly high gloss, are not materially affected by water or, after drying, by oxygen, the protecting power depending on the proportion of oil to thinner, the covering power to the quantity, composition, and state of subdivision of the pigment. These are ordinary paints.
1. Catalysis and oxidation in paint drying.
- C. Paints similar in composition to the above, but containing a resin, natural or synthetic, instead of a pigment. These have similar surface and protective

characteristics to paints, but are transparent, and spread more easily. They are varnishes.

- D. Paints similar to the above, but containing both a pigment and resin. These are enamels. The term is sometimes loosely applied.
 - E. Paints containing a resinous material, either natural or synthetic, which form a continuous film similar to that of the polymerized oil in paints on the simple evaporation of the solvent in which it is dissolved. Such paints contain no oil, and may or may not contain pigments. They are known as lacquers.
- IV. What are the chemicals employed in making these materials and what are their properties?
- A. The oils.
 - B. The resins.
 - C. The solvents. Brief consideration, indicating organic nature to be discussed later, in 245, but providing sufficient background for understanding of the nature of the total problem.
 - D. The pigments and covering agents.
 1. For water paints-- CaSO_4 , CaCO_3 .
 2. White pigments for non-aqueous paints.
 - a. Lithopane--30% ZnS + 70% BaSO_4 .
 - b. Cryptone-- ZnS .
 - c. Blanc Fixe-- BaSO_4 .
 - d. White lead-- $\text{Pb}(\text{OH})_2 \cdot 2\text{PbCO}_3$. Dutch process for making.
 - e. Titanium oxide-- TiO_2 .
 3. Black pigments.
 - a. Carbon black.
 4. Yellow pigments.
 - a. Lead chromates co-precipitated with lead sulfate. Various shades produced, varying in sp. gn., oil absorption, light fastness, tendency to bleed, etc.
 - b. Zinc chromate--really, complex salt of zinc and potassium chromate. Has a relatively high solubility. Tends to bleed in water, but is very good rust inhibitor.
 - c. Cadmium yellow-- CdS .
 5. Red pigments.
 - a. Cadmium sulpho-selenides.
 - b. Vermillion HgS .
 - c. Red lead--really used in spite of color because of very high permanency and covering power-- Pb_3O_4 .
 - d. Venetian, or barn red-- Fe_2O_3 .

6. Blue pigments.

- a. Ferrous ferrocyanides, oxidized to blue pigments (ferric ferrocyanide). Oxidized form cannot be used in paint very well, as it is reduced to original white form by linseed oil. Nomenclature confused. Possess strong tendency to bronze--those showing least such tendency being hardest to disperse. Sensitive to alkali.

7. Green pigments.

- a. Cr_2O_3 . Extremely resistant to all changes--alkali, acid, heat, light, but not especially brilliant. Much more brilliant, and much more expensive as hydrate.
- b. Chrome greens. Mixtures of iron blues and chrome yellows. Sensitive to alkali due to presence of iron blues.

8. Brown pigments.

- a. Burnt umber, burnt sienna, etc. Natural mineral mixtures of Fe and Mn compounds.

E. Certain inorganic aspects of the use of organic pigments. Many organic dyes of complex structure are used in paints, lacquers, and enamels. These pigments are available in much greater variety than inorganic pigments, and are often much more brilliant and have greater tinting power, but they cannot ordinarily be used as pure compounds, because they are not usually soluble in paint vehicle, and could not be properly dispersed as solids. They are therefore sorbed on white or colorless materials, such as CaCO_3 or $\text{Al}(\text{OH})_3$. The resulting pigment powder is called a lake.

V. What chemical factors affect the deterioration of surface films? A painted surface, of course, simply constitutes a new surface which reacts chemically as though the entire structural material were composed of it, until the surface disintegrates at some point, and the structure is exposed. Paint surfaces are, of course, usually more resistant to weathering action than the surfaces of the structural material itself; that is why they are used. But they are not completely resistant. Abrasion, solution, hydrolysis--all these play a part in the eventual dissolution of a paint. In addition, the paint is susceptible to certain destructive changes characteristic of it alone:

A. Photochemical decomposition.

- 1. Of the film. The film of polymerized ester, or cellulose nitrate or acetate is somewhat susceptible of photocatalytic decomposition, resulting in cracking. Pigment absorbs light, retards this action.
- 2. Of the pigment. Many of the pigments, particularly the organic ones, are slowly decomposed into lighter or colorless substances photochemically. This is true fading.

B. Chalking. As the resin or polymer film weathers and is destroyed, the refractive index of the film changes. This is accompanied by an apparent whitening of the film

particularly if the pigment consists of a mixture of colored and white ingredients. This is not true fading, as it may be reversed by painting with additional oil or colorless lacquer, and thus restoring the film. Discussion of refractive index.

- C. Specific chemical changes, peculiar to certain pigments, i.e., whitening of red lead through surface conversion of PbCO_3 .
- D. Deplasticizing, blistering, and cracking.

EXPERIMENT D

To Synthesize Certain Common Paint Pigments

1. Blanc Fixe

To a 100 mm test tube one-third full of water add one cc. of dilute H_2SO_4 and two cc of $Ba(NO_3)_2$ solution. Shake, and centrifuge until the solid has gathered in the bottom of the tube. Remove the supernatant liquid with a medicine dropper, refill the tube one-third full of water, shake, and again centrifuge. Remove the supernatant liquid with a medicine dropper, reject it, and again fill the tube one-third full of water. Save for later portion of experiment.

2. Chrome yellow

To a 100 mm test tube one-third full of distilled water add one cc of $Pb(NO_3)_2$ solution. Shake, and add 15 drops of K_2CrO_4 solution. Shake, centrifuge, reject the supernatant liquid with a medicine dropper, refill one-third with distilled water, shake, and again centrifuge. Reject the supernatant liquid with a medicine dropper, and fill one-fourth full with distilled water. Save for later portion of experiment.

3. White Lead

To two cc of Na_2CO_3 solution, add enough water to fill a 100 mm test tube one-third full, and shake well. Add to this one cc of $Pb(NO_3)_2$ solution, and shake well. Centrifuge the mixture, then remove the supernatant liquid with a medicine dropper and reject it. Refill again to one-third with water, shake, centrifuge, and again reject the supernatant liquid. Refill again with water, and save until later part of experiment.

4. Chrome green (Students may work in groups of three on this preparation.)

In a mortar and pestle, grind to a fine crystalline powder several crystals of ammonium dichromate. BE VERY CAREFUL NOT TO ALLOW ANY DUST, CARBON, OR OTHER ORGANIC MATTER TO BECOME MIXED WITH THE DICHROMATE NOW OR AT ANY LATER TIME DURING THE EXPERIMENT. Take a piece of Mg ribbon about 8 cm. long, and twist and bend it so that a coil of it can rest in the bottom of the crucible, and a "wick" of the metal reach up above it. Place the coil of Mg in the crucible, cover with the ground dichromate so that the crucible is not more than one-fourth full, place the crucible in your pneumatic trough, and set fire to the wick end of the ribbon. Save the material formed for the latter portion of the experiment.

5. Prussian Blue

To one cc of $FeCl_3$ solution in a test tube (100 mm) add enough water to fill the tube one-third full. Then add two cc of potassium ferrocyanide solution. Centrifuge for about

ten minutes, and remove the supernatant liquid with a medicine dropper (a longer period of centrifuging may be required). Remove the supernatant liquid with a medicine dropper, and refill with water to one-third capacity, and repeat centrifuging operation, rejecting supernatant liquid each time. Finally, refill the tube to one-third capacity with distilled water, and save for final portion of experiment.

6. Zinc White

To a 100 mm test tube one-third full of distilled water, add one cc of Na_2S solution. Shake, and add one cc of ZnCl_2 solution. Shake, centrifuge, remove and reject supernatant liquid, refill to one-third capacity with distilled water, shake, centrifuge, and reject supernatant liquid. Refill to one-third capacity with distilled water, and save for latter part of experiment.

7. Madder Lake

To one and one-half ml. of NH_4OH in a 100 mm test tube, add enough distilled water to fill test tube one-third full, then add five drops of alizarine paste, and two drops of turkey red oil. Shake, then add dropwise $\text{Al}_2(\text{SO}_4)_3$ solution until the tube is about three-fourths full, or until there is a considerable lightening in the color of the solution. Centrifuge, reject supernatant liquid, refill to one-third full, shake, centrifuge, reject liquid, and refill to one-third full and save for latter part of experiment.

Shake up each of the test tubes containing pigment, and with a medicine dropper, transfer two drops of the suspension of each pigment to each of three depressions in your spot plate. Repeat this for all six of the pigments, and also place a few grains of the ignition product of the ammonium dichromate in each of three depressions of your plate.

To the first of the three depressions in each of the seven series add six drops of dilute HNO_3 . To the second, six drops of H_2S solution and to the third, add six drops of dilute NaOH . Make a table showing your results in each case.

Questions:

1. Give the chemical name, formula, and reaction of formation of all the pigments synthesized, except the madder lake. In what most important way does the madder lake differ from all the other pigments synthesized?
2. Summarize in a table the results obtained by testing each of your pigments with H_2S , HNO_3 , and NaOH . Explain all reactions observed from a chemical viewpoint.
3. What is the purpose of the second centrifuging in the preparation of each of the pigments prepared in aqueous media?

REVIEW QUESTIONS--CHEMISTRY 144

The final examination to be given in Chemistry 144 will cover the work of both semesters, that is, of Chemistry 134 and of Chemistry 144. You should go back over the mimeographed materials handed to you during the course of the first semester, particularly the selection sheets, which list the topics (problems) which we discussed within the first area and the second, and the series of sheets analyzing the problems in area one. The following procedure is suggested as a fairly effective way of reviewing:

1. Carefully go over your old selection sheets, taking note of the following data: (1) what problems were covered, and (2) what references were cited to each problem. These references in area one are cited right on your bibliography sheet. In area two, the bibliographies as you will recall, are still on reserve in the library, bound in brown manila covers.
2. Outline, on paper, from memory, the important issues involved in each problem, from a chemical viewpoint. Remember that the course is more concerned with issues than with isolated facts, although these too have their importance.
3. Consult these review sheets, and use the questions asked on them to fill out and add to your own outlines. Be sure that you see the relationships between the outlines of the problems, which you have made, and the questions included on the review sheets.
4. Using the references mentioned above, go to the library, and seek out the answers to all questions in your review sheets or outlines which you have previously made.
5. Consult the instructor concerning any questions to which you cannot find answers.

Review Questions--Area One

1. Describe the structure of the silver atom in terms of electrons, protons, and neutrons.
2. What do we mean by atomic number?
3. What is the relation between atomic number and atomic weight?
4. What do we mean by a "shell" of electrons?
5. What determines the number of electrons that can be held in any given shell of an atom?
6. What is meant by s, p, d, and f electrons?
7. How does the periodic chart come to be built up?
8. What can be said of the number of electrons in the outermost shell of the sodium, potassium, and lithium atoms?

The chlorine, bromine, and fluorine atoms?

9. What is the relation between the number of electrons in the outer shell of an atom and the activity of the element of which this is an atom?
10. What, in general, is the difference between active metals, less active metals, less active non-metals, active non-metals, and inert gases in terms of the number of electrons in the outermost shells of the atom?
11. What is meant by the electromotive series of elements?
12. What happens in terms of electron flow when a piece of iron rusts in water?
13. Would you expect copper or cast-iron pipe to stand up better in a system in which slightly acidic water was allowed to flow? Why?
14. Discuss the advantages and disadvantages of lead as a metal for plumbing installations.
15. Why is copper smelting often a menace to surrounding agriculture?
16. What by-products of the electrolytic purification of copper are often of sufficient value to pay for the cost of the current?
17. How is steel made? Distinguish between pig iron, cast iron, steel, and stainless steel.
18. What is meant by case-hardening of steel? Compare case-hardening of steel with casting of iron in chemical effects.
19. Discuss aluminum in terms of commonness, form of occurrence, means of purification, and isolation.
20. Explain the importance of the Al_2O_3 film in aluminum cooking utensils.
21. What three metals are our best electrical conductors?
22. Is copper or aluminum the better conductor in wire of equal cross-sectional area? In wire of equal weight per unit length?
23. Explain how galvanizing makes iron more resistant to weather?
24. Describe the location in the world, and the mode of occurrence, of each of the following metals: Al, Fe, Cu, Sn, Zn, Ni.
25. What factors are most important in preventing the use of silver as a lining to replace essential tin in tin cans?
26. Explain why aluminum was not commercially available in any quantity until this century, while copper, which is much less common, was known in prehistoric times?
27. List the compositions, properties, and major uses of each of the following alloys. What is the most abundant metal in each?

Wood's metal, aluminum bronze, bronze, brass, steel, invar, permalloy, solder, nickel silver, Dow metal, sterling silver, rose metal, pewter, Allegheny metal, Monel metal, and other common alloys you can think of.

28. Explain the role played by water in the corrosion of various metals.
29. How is the action of water changed if it contains extra acids? Oxidizing agents? Explain in terms of electron transfer.
30. Explain how you would use the electromotive series in helping you choose metals for various household uses.
31. List three substances commonly found in tooth powders, and explain how each contributes to the action of the powder.
32. Classify each of the following materials into one of the following groups: Metaphen, merthiolate, Zonite, sulfathiazole, formalin, phenol, arsphenamine, mercuric chloride, iodine:
 - a. Specific poison for particular micro-organism.
 - b. General poison to micro-organisms, generally harmless to protoplasm of higher animals.
 - c. Oxidizing agent, toxic to all cells with which it comes in close contact, but doing only restricted tissue damage.
 - d. Protein coagulant, toxic to all forms of protoplasm, but not strong enough to do severe damage to human tissue.
 - e. Protein coagulant so severe in action as to be usable only as a disinfectant for inanimate objects.
33. Distinguish between paints, lacquers, varnishes, enamels, and calcimine.
34. List, and give the chemical composition and properties of six major paint pigments.
35. In what way does painting protect the surface of a material? What chemical properties does this require a paint to have?
36. List the constituents of a paint, tell what kind of thing each is chemically, and explain the function of each.
37. How does a paint dry?
38. Distinguish between a vaccine, a serum, an antitoxin, and a toxin-antitoxin.
39. How is ordinary glass made? How is pyrex glass made? In what component do they differ chiefly? In what property?
40. What effect does increasing the amount of SiO_2 used in a glass batch at the expense of other ingredients have on its resistance to thermal fracture? To attack by alkalis?
41. How are colored glasses made?
42. What is the most important industrial effect of including lead oxide in a glass-making batch?
43. How does the strength of the intramolecular bond of macromolecules or crystals affect the suitability of certain materials for structural purposes?
44. How is Portland cement made, how does it harden, and of what is it chiefly composed?

45. What is the difference between china and earthenware? Of what is each made? What is the composition of a typical glaze?
46. Explain why a smaller volume of water is needed as steam in a radiator in order to keep a room warm than if the water were used as hot water at its boiling point in a hot-water radiator.
47. Explain why an enameled pot is not damaged if used to boil water furiously on a stove, but becomes severely damaged if heated at a much smaller rate while empty.
48. Explain why energy must be expended to cool the interior of a refrigerator. Where does the energy taken from the inside of the refrigerator go?
49. What temperature effect is observed when NH_4Cl is dissolved in water? When H_2SO_4 is dissolved in water? Explain in both cases.
50. Would it be possible to use the electricity obtained from a turbine installed in a waterfall to operate a pump to send the water up to the top of the fall again? Explain.
51. What do we mean by change of state? By specific heat? By heat of vaporization? By heat of fusion?
52. Explain the difference between heat and temperature on the basis of the kinetic-molecular theory. Justify Dulong and Petit's law.
53. What happens to the heat which is used to melt ice, since the temperature of the water is not changed in this process?
54. What is a calorie? Is a calorie the same kind of thing as a watt? As an erg? Explain.
55. Describe in detail how city water may be purified.
56. Exactly what is the function of the chlorine, the charcoal, the alum, and the calgon, in modern water plant practice?
57. Why are water purification standards stated partially in terms of content of the harmless *B. coli*?
58. What facts may be determined by scientific examination of blood stains?
59. Describe and explain the principle involved in the three commonest methods of developing latent fingerprints.
60. What characteristic of ink is it which makes detection of forged documents a comparatively simple task? What is ink? How do inks differ?
61. Explain the role of oxidation in causing a fire, or maintaining one. Distinguish between oxidation and combustion.
62. Why must a fire be a kind of chain reaction?
63. Are oxidations the only exothermic reactions? Why are all fires associated with oxidation?
64. Explain the principle of the Permutit water softener. What do we mean by hard water? Suggest other methods of softening water.
65. What chemistry is involved in the operation of the cess-pool?

66. How do materials used to extinguish fires operate? How does water put out a fire?

Problems

1. A three-kilogram roast is removed from the oven at a temperature of 100°C and placed immediately in an ice-box, where it is cooled to a temperature of 10°C . If the specific heat of the meat is $0.7 \text{ cal/gm/degree}$, the heat of fusion of ice is 80 cal/gm , and the water from the melted ice is drained off immediately, how many grams of ice will be melted in cooling the roast?
2. Assuming that the specific gravity of vinegar is the same as water, the molecular weight of acetic acid is sixty, and acetic acid contains only one ionizable H atom per molecule, and that there is 5 per cent acetic acid in vinegar, what is the normality of vinegar in acetic acid?
3. A solution of sulfuric acid contains 49 grams of acid in 250 ml. Fifty ml. will neutralize 270 ml. of NaOH solution. What is the normality of the NaOH solution?
4. What weight of $\text{Al}_2(\text{SO}_4)_3$ would be needed to make 260 ml. of 0.2 N solution?

APPENDIX B

ANONYMOUS STUDENT COMMENTS ON EXPERIMENTAL
PROGRAM. THIS MATERIAL IS REPRODUCED
AS WRITTEN WITHOUT CORRECTION

ANONYMOUS STUDENT COMMENTS ON
EXPERIMENTAL PROGRAM

1. My main objection to the course is the fact that we do not explain all of the topics thoroughly enough. Another objection is that many of us still do not know how to work chemical equations.

I have enjoyed the course, and I like our general method of study. We have approached both the chemical view and the practical view.

2. In this course we have learned more how to apply chemistry to our daily needs. Such a course is very practical. However, I was unable to grasp some of the basic fundamentals of chemistry which are dwelt upon more extensively in other chemistry courses. The course, as a whole, has been very profitable to me.

It is true that we must learn how to apply the knowledge which we obtain. But this cannot be done until we have a thorough conception of the rudiments of chemistry.

3. We, being an agriculture group of students, were taught along on something that would be practical and of value to us in everyday life. This course was not especially designed for teaching one how to do formula writing, but rather to make us familiar with chemical terms and to teach us the content of an element or compound. Then too, we tested each thing to find its properties, to see the chemical change or reaction, and to be able to tell whether it would be profitable as something for common use or not. In many instances in this course we have been allowed to think something out ourselves and have been required to search for our own reading material. This was on the whole very good training.

There is only one objection I would have to this course. That is this, that the person taking it should first have an excellent background or fundamentals for chemistry so he can easily understand what is taught.

4. It seemed to me that if we could discuss the experiments after they had been performed instead of before, the material would be easier to grasp. I got very little out of some of the discussions because I did not understand just what the nature of the experiment would be.

5. This chemistry course was very hard for me to understand in the first classes. The course was very new and different from what I was accustomed to.

I was very much surprised after our first test to find that I had really learned quite a large amount of chemistry, and also how to think or reason the questions out.

As the course went on, I liked it more each time we met lab or lecture. I am more pleased with the course after talking to the fellows in the other class who tried

to pass our final examination. The other fellows did not understand our exam and thought that it was very difficult.

6. I think this class is superior to the other class as the subjects are concerned with everyday life and conditions one might even run into. But I believe to simplify this course will bring much better results.
7. As you already know this was a strictly lecture course with no books. I personally like a lecture course because a person would not study chemistry out of a book even if he had one. Therefore, you can learn more from a lecture class.
 Another criticism is the \$7.50 fee it cost to take the course. I do not see how if you bought your books that it would cost you \$7.50.
 As to the work we covered, it was very practical and helpful either to one who intends to farm or one who is going to have anything to do with a farm or farming problems. I do believe that we could have stressed chemical formulas more, as I would like to know more about them. Another thing is that I think that the instructor took too much for granted and thought we knew more than we really did; thus making it hard for us.
 The laboratory work was very simple, but the writing of the equations was hard, even though you understood the process which you had completed. This point should be improved by the instructor holding the quiz section after and before they were in the laboratory.
8. I think it is the hard way to get what we are after. It may be that it is because we are used to studying from a book. What we have learned so far though is practical. I believe a longer lab period would help, and a few more tests would be justified.
9. This course is pretty well organized. The method of class discussion would be more interesting if more experiments were performed by the instructor, and also if the instructor would be more stringent and not let the boys on the back row go to sleep.
 The method of having a quiz section is a very good idea as it gives the student a basis for every answer on the experiment. I think the course was hard to understand at first, but after several days you begin to get the idea.
10. At the beginning of this course I thought that it was going to be very hard and dull, but after the course had gotten under way, I decided that it was the most interesting course that I had ever taken. The reason that I liked the course so well was due to the fact that it is more practical. I believe that all students in the school of agriculture that take 134 Chemistry should be taught this way because it is more practical. Although I did not do so well on the reports, I thought that they were very interesting because you can learn more things that will help you later in life. I do not know of any part that is wrong with this course.
11. This course does not dwell on one topic long enough for a student to learn enough about that topic. Your lec-

tures are too hard to understand because you use too many big words that we do not understand the meaning of. I have enjoyed the lab work and the class because it is interesting to work out these experiments, and I think it has achieved the result desired fairly well.

12. Without specific reading assignments I feel that the average student will do very little reading. There are a few weak points in the lecture. The material is usually well covered, but it is virtually impossible to take a reasonable set of notes. Due to the fact that there is no specific assignments or reading material the students lack in the basic facts and rules of chemistry.
13. I think this is the most practical method of teaching chemistry. We have learned more things about chemistry that will be of great use in the future. I like this method as it is, and I hope it does not change.
14. I liked this course in chemistry very much; however, I do not like a few of the points on the tests. The main one is the questions that you answer true or false and then have to list the reasons on the above statements. It is too complicated and hard to understand.
I like the way the lab classes were held and also the way the experiments were written out for us. But I would rather write a written report on each experiment instead of answering the questions.
I do not like the charge of ten cents for each time to open your locker when you leave your key at home.
15. The objectives of this course seem good, but do not appear to be as orderly as in regular courses of this type. It seems hard to distinguish the exact things I have learned, but in most cases it seems that I really have learned as much as from other courses if not more.
In our chemistry lab procedures it seems as though they might have been made somewhat clearer. In most cases I feel we see the reaction or smell it or feel it but really do not have much idea of what caused it. It always seemed a little doubtful to me what the benefit would be unless I know exactly what was happening when it happened.
The using of the library for material seems a good idea to me, but it requires much outside work and reading.
Perhaps performing similar experiments to the ones we are to have and pointing out and explaining what happens would help.
16. I think we should have a text book. Then we could get some knowledge for ourselves. I do not think it is a good idea because we were not given any formulas to learn, and when we went to look for a solution we just had to look at random or ask somebody else.
17. I think this course is the average good course and is well applied. I think compared with other courses it is as good or better a course than any I take. It is OK.
18. The course was very different from any course that I have taken in high school or college. I still believe that the standard methods of teaching are the best. However, I have learned a lot about chemistry during this semester. It may be the best method of teaching it, but I am thoroughly convinced as yet. I guess I take this

attitude because it is so far different from anything that I have ever had before.

I like the idea of taking up problems in areas and dividing the area into topics. Then one can choose a topic that most appeals to him. I think our course is more practical than the other section of 134 Chemistry.

19. Have a text book to use in class and home study.
For the teacher not to walk up and down in front or behind his desk, for it makes the students watch him and it also makes them sleepy or drowsy and they do not pay any attention in class.
Research material on each experiment.
20. I think our course in chemistry was a decided success from the experimental point of view, even though there are a lot of changes that could be made that help us students understand the course more.
One way this course could be improved would be for our teacher to break each thing he says down into smaller words that we could understand better. He has just learned his chemistry in that way which makes it hard for him to tell, and teach us; but I think if he would use smaller words the student would get 90% more out of the course. As a man, I think Mr. Freidenberg is one of the best. I have had more fun, and at the same time learned more by knowing Mr. Freidenberg as a man than any other teacher I have ever had.
The course could be improved by handing out explanation papers with each experiment, so we could know a little more about each one. Another thing about the course I liked very much was the meetings each Monday night, and I think they helped very much toward a better understanding of the course. I just wish every member of the class could have attended those meetings.
21. I think that if we had used a text book and had studied it we would have learned more than we would have from our lectures. By studying something over and over I think that we will remember it where as when we hear something one time we forget it. When reading books which we check out they sometimes do not make it as clear as a text book does.
22. I liked the course fine, but I do not think we had enough basic knowledge of chemistry for some of the work we took up, especially that which we took up the first of the year. I believe all the subjects we took up will be of much use to us all. I especially like the way we may do our outside assignments (the reports) because instead of just having to do a little before each class, we may have hours at a time to work on reports.
23. The semesters work was really alright with me. I only wished I had had more time to spend on the subject, not necessarily in the classroom or lab, but outside of class and lab.
24. I liked the course very much. I feel that it has helped me very much. Although I did feel at the beginning that it would be a boring course, I found that it just what one makes it.
I believe that the course is being taught in the

proper procedure, and I believe that this procedure is the only way that we could get the most out of the discussion. I believe that the use of more mimeograph explanations and more blackboard explanations would be a big help.

25. One thing that I think we should have learned was the formulas or the symbols for all the elements. We learned more how to apply it but when some formulas were in the experiment we never knew what it was.
26. I think the course was interesting in several respects, but I do think it was dry to me for about two months before I caught on to how to adjust myself to the procedures of this course. I think a little more writing on the blackboard would help the students more than just hearing what is said in class.
27. I think the main fault of this course is that we have not been taught formulas, and that the course started out as though we had already been "exposed" to chemistry. Outside of the above mentioned facts the course was very good.
28. I believe the course could and would be of much greater value and help to the student if it stuck closer to the fundamentals of chemistry. Conducting an experiment group might be all well and good, but it should not be done at the sacrifice of the student's needed knowledge of fundamentals of chemistry. Agriculture students are going to need to know basic chemistry before they can do any good in the sophomore course--soils; and if they do not learn it in 134 and 144, a great hardship will be worked on them. They will be unfairly handicapped. It would not be so bad if all the students who take soils had been in an experiment group, but the experiment students would be at a disadvantage to students who had learned some chemistry--such as Lee's students. I am not positive yet as to how much experiment students will learn in a year, but ask any of them how much they have learned this half year.
29. The lectures are very good if one had enough knowledge in chemistry to understand them. They are given in such a way as to put them to their uses, both good and bad points about each thing, but it is usually too scientific to understand.
The exercises are explained fully or seem to be, but the problems or calculations are very difficult and hard to understand.
30. I think this is a very good course in chemistry and is very beneficial to the Freshman in college. The only thing I have against this course is that there is not anything to fall back on. What I mean is a textbook or some written outline that can be followed.
I believe that we have studied some things that will help us out later on in life. There are many of us who will be in the Army next semester and will have gotten some things out of this course that we would not get in a regular chemistry course.
31. I have always thought that the teaching of chemistry was done along definite channels. I thought that such things as the writing of chemical formulas and learning

the chemical symbols were a part of this basic training. I was very disappointed in this chemistry course during the first part of the year, and I always will think that something very important has been left out. On the other side I believe that this is the most interesting chemistry course offered to the Freshman class.

32. This is a practical application of chemistry, but it does not go deep enough into the working of problems and the use of formulas. We do not know anything about where the equations come from. We only know that we have them and use them.

I believe we accomplish more in the lab than we could in theory and for that reason I think we should put more emphasis on the lab work. I like the form of test given in this class, but the other tests deal with the more practical problems.

I do not believe we have had enough basic chemistry, and that is what we will need when we take advanced courses in this subject. If we should ever take chemistry under another instructor and he used the old method, we would be totally lost.

33. I think that I should say that I have never taken a chemistry course before, and therefore cannot compare this course to another. The good points of the course are numerous. I learned very much in my work, especially in the laboratory and also in writing my reports. In the lecture and quiz part, however, I fell short. I can hardly say what the reason is, except that I do believe that I would have learned more had I have had a textbook to study. I am sure I would have received more from the lecture had I have been able to understand the teacher. I am sure this was no fault of the teacher especially, I just did not understand him.

I do not feel that I could take another course in chemistry unless I took a continuation of this course. I do not plan to do this, however, because I have talked to my dean and I am going to take more math so as to be more fitted for the Air Corps. I am in the reserve and expect to be in pretty soon and want to have as much math as possible.

APPENDIX C

CONTROL GROUP FINAL EXAMINATIONS

THIS MATERIAL IS REPRODUCED ESSENTIALLY AS
ADMINISTERED, WITHOUT CORRECTION

FINAL EXAMINATION

Chemistry 134

- I. Select the statements which are correct and blacken the corresponding spaces on the answer sheet. There may be more than one correct statement within each group. Score = number right - number wrong so DO NOT GUESS.
1. According to the kinetic-molecular theory:
 1. The molecules of a gas are relatively very far apart.
 2. The molecules in a liquid are much closer together than are those of a gas.
 3. The molecules of a solid are not in motion.
 4. The pressure of a gas is due to the molecules striking the walls of the container.
 5. The velocity of the molecules is decreased as the temperature is increased.
 2. According to the atomic theory:
 1. A compound always contains at least two elements.
 2. A compound is made up of unit bodies called atoms.
 3. The average weight of oxygen atoms is the same as the average weight of nitrogen atoms.
 4. Two elements can unite in more than one proportion.
 5. Fractions of atoms may take part in a chemical reaction.
 3. Liquids:
 1. May be transformed into gases by greatly increasing the kinetic energy of the molecules.
 2. Absorb heat when converted into solids.
 3. Contain more energy than would the same amount of the same substance in the solid state.
 4. Possess identical heats of vaporization.
 5. Exhibit surface tension because of the intermolecular forces present.
 4. The boiling point
 1. Is that temperature at which the vapor pressure of a liquid is equal to the atmospheric pressure.
 2. Is lowered by a decrease in the vapor pressure of the liquid.
 3. Is increased by a decrease in atmospheric pressure.
 4. Of a volatile liquid is lower than that of a non-volatile liquid.
 5. Of a liquid having a high vapor pressure is lower than that of a liquid having a low vapor pressure.
 5. H_3PO_4
 1. is the formula of a chemical compound.
 2. contains eight atoms.
 3. contains four elements.
 4. is the equation for a mixture.

5. is an abbreviation which tells us the elements and the number of atoms of each element present in one molecule of this substance.
6. Oxygen
 1. is the most common of all the elements.
 2. is prepared commercially by the liquefaction and fractional distillation of air.
 3. combines directly with most of the elements.
 4. is very reactive at 25°C.
 5. is necessary for the production of energy within the human body over a prolonged period of time.
7. Hydrogen
 1. is the lightest known element.
 2. may be produced by passing steam over hot carbon dioxide.
 3. is non-flammable.
 4. is used to convert vegetable oils into solid fats.
 5. and oxygen are formed during the electrolysis of water.
8. Water
 1. reacts with basic oxides to form acids.
 2. in the form of ice has the formula H_2O_2 .
 3. is found in most anhydrous materials.
 4. is found in hydrates in the form of water of crystallization.
 5. which is said to be soft is chemically pure.
9. Conditions necessary for spontaneous combustion are:
 1. Oily rags or hay must be present.
 2. Oxidation must be taking place.
 3. Air must not be present.
 4. The heat produced must be allowed to escape.
 5. An easily oxidizable material must be present.
10. Conditions which might affect the rate of oxidation of a material are:
 1. The temperature at which the reaction is taking place.
 2. The concentration of oxygen.
 3. The kindling temperature of the oxygen.
 4. The presence or absence of a catalyst.
 5. The particle size of the material undergoing oxidation.
11. An element has an atomic number of 9 and atomic weight 19.
 1. Nineteen protons would be present in the nucleus.
 2. Nine neutrons would be present in the nucleus.
 3. Nine electrons would be present in the orbits.
 4. One electron would be present in the valence orbit.
 5. The valence of the element would probably be +1.
12. A catalyst
 1. always increases the speed of a reaction.
 2. is always destroyed during the progress of the reaction which it catalyzes.
 3. is a living organism.
 4. which speeds up the rate of a reaction is called a positive catalyst.

5. may start a reaction.
 13. An element
 1. is a gas.
 2. resists all ordinary attempts to decompose it.
 3. is made up of unit bodies called atoms.
 4. is often represented by a suitable abbreviation which we call an equation.
 5. is variable in composition.
 14. A compound
 1. is variable in composition.
 2. cannot be decomposed by ordinary chemical means.
 3. possesses the same chemical properties as the elements from which it was formed.
 4. is a mixture of elements.
 5. is formed by the transfer or sharing of one or more electrons between atoms.
 15. Energy
 1. as heat, is absorbed by the ice when water freezes.
 2. is neither created nor destroyed in ordinary chemical reactions.
 3. is liberated in the form of heat by an endothermic reaction.
 4. is the ability not to perform work.
 5. is utilized for work by the human body only if it is heat energy.
- II. Choose the term which is best defined or described by the statement and blacken the corresponding space on the answer sheet. Score = R-W/5
16. The process of separating a solid from a liquid by means of a porous substance through which the liquid passes.

1. Decaptation	3. Vaporization	5. Extraction
2. Filtration	4. Absorption	
 17. The quantity of heat liberated or absorbed when a unit quantity of a solid is melted without any change in temperature.

1. Heat of solution	3. Heat of dilution	5. Heat of vaporization
2. Heat of fusion	4. Heat of water	
 18. Any one of a number of atoms differing in mass but having the same atomic number and chemical properties.

1. Isotherm	3. Isotope	5. Isomorph
2. Isomer	4. Allotrope	
 19. The mass of a unit volume of matter.

1. One gram	3. Molecular weight	5. Specific gravity
2. Atomic weight	4. Density	
 20. Distribution of the molecules of one substance among those of another in the absence of any external force.

1. Viscosity	3. Chemical reaction	5. Diffusion
2. Evaporation	4. State of equilibrium	

21. An atom which has gained or lost one or more electrons.
 1. Molecule 3. Ion 5. Isomer
 2. Beta ray 4. Isotope
22. The temperature at which both solid and liquid remain in contact with each other without any change in temperature.
 1. Degree centigrade 3. Boiling point 5. Critical temperature
 2. Sublimation point 4. Melting point
23. A process in which a substance which is a solid is transformed to a gas without going through the liquid state.
 1. Sublimation 3. Vaporization 5. Dispersion
 2. Condensation 4. Fusion
24. A measure of the intensity of heat.
 1. Thermometer 3. Calorie 5. Temperature
 2. Specific heat 4. Therm
25. A liquid is vaporized and the vapor is condensed back to a liquid.
 1. Distillation 3. Sublimation 5. Transition
 2. Evaporation 4. Fusion

III. Indicate which item or items in the column at the left best matches the statements or terms given on the right.

- | | |
|----------------------------|---|
| 1. 22.4 | 121. Avogadro's number. |
| 2. 6.06×10^{23} | 122. No. of ml' in one liter. |
| 3. 1000 | 123. Standard temperature. |
| 4. 6.06×10^{22} | 124. Gms in one kg. |
| 5. 273°A | 125. Gm.-Molecular volume. |
| 6. 0°C | 126. Standard pressure. |
| 7. 10 | 127. No. of protons in the nucleus of the hydrogen atom. |
| 8. 1 | 128. Atomic weight of deuterium. |
| 9. 2 | 129. 32°F . |
| 10. 373°A | 130. mm in 1 cm. |
| 11. 3 | 131. Boiling point of water. |
| 12. 32 | 132. The number of atoms of oxygen in one molecule of ozone. |
| 13. -273°C | 133. Molecular weight of oxygen. |
| 14. 5 | 134. The atomic number of helium. |
| 15. 760 | 135. The density of a solid. 20 gms of it displace 4 cc of water. |

IV. Use the equation given, the table of atomic weights, and the electromotive series to decide whether statements 61-70 are true or false. Blacken the appropriate space on the answer sheet. Score = R - W.



61. H_2 represents two molecules of hydrogen.
62. There are two molecules on each side of the arrow.
63. This is a shorthand way of saying that zinc will react with hydrochloric acid to produce zinc chloride and hydrogen.
64. There are four elements involved in this reaction.

65. If the valence of Zn is +2 and that of Al is +3, the formula for the compound of Al and Cl will be Al_3Cl_2 .
 66. If the valence of Zn is +2 the valence of hydrogen must be +1.
 67. If the valence of Zn is +2 it must lose two electrons when it reacts.
 68. Zn is reduced in this reaction.
 69. Copper could be substituted for Zn in this reaction and H_2 would still be produced.
 70. Four gms of hydrogen would be produced by the reaction of 130 gms of Zn with HCl.
- V. Decide whether the following statements are true or false and blacken the appropriate space on the answer sheet.
Score = R - W.
76. 400 mg = 14 gm.
 77. 250 ml = 2.5 liters.
 78. The product of the reaction between oxygen and another element is known as an oxide.
 79. Combustion is very rapid oxidation in which energy is given off as heat and light.
 80. The oxy-hydrogen torch is widely used because of the extreme heat generated by the oxidation of the hydrogen.
 81. The heat of vaporization of a substance represents the energy required by the molecules to overcome the inter-molecular forces and to expand against the pressure of the atmosphere.
 82. Lithium will displace Ag from a solution of a silver salt.
 83. Oxidation is the loss of electrons.
 84. An amorphous solid possesses a definite crystalline structure.
 85. Compressed gases cool their surroundings when the gases are allowed to expand.
 86. The freezing of water is a chemical change.
 87. Acids turn red litmus blue.
 88. The molecular weight of $\text{Ca}(\text{HCO}_3)_2$ is 162.
 89. Bromine has 7 electrons in its outer orbit. The valence of bromine is probably +1.
 90. Under normal conditions water has its greatest density at 4°C .
- VI. Work this problem on the back of the answer sheet. SHOW ALL WORK. Possible points = 10.

When a weld is made by the Thermit process, the iron in Fe_2O_3 is reduced to Fe by means of Al. The aluminum is converted into Al_2O_3 . The heat produced by this reaction is sufficient to melt the Fe which runs into a mold around the parts to be welded. What weight of Fe_2O_3 would have to be used if 1 kg of molten iron were required for the weld?

Name	Atomic Number	Atomic Weight	Electromotive Series
Aluminum	Al 13	26.97	
Argon	A 18	39.94	Lithium
Arsenic	As 33	74.91	Potassium
Barium	Ba 56	137.36	Sodium
Bromine	Br 35	79.916	Calcium
Calcium	Ca 20	40.08	Magnesium
Carbon	C 6	12.01	Aluminum
Chlorine	Cl 17	35.457	Manganese
Copper	Cu 29	63.57	Zinc
Fluorine	F 9	19.00	Chromium
Gold	Au 79	197.2	Iron
Helium	He 2	4.00	Cadmium
Hydrogen	H 1	1.008	Cobalt
Iodine	I 53	126.92	Nickel
Iron	Fe 26	55.84	Tin
Lead	Pb 82	207.21	Lead
Magnesium	Mg 12	24.32	Hydrogen
Manganese	Mn 25	54.93	Copper
Mercury	Hg 80	200.61	Arsenic
Nickel	Ni 28	58.69	Mercury
Nitrogen	N 7	14.008	Silver
Oxygen	O 8	16.00	Platinum
Phosphorus	P 15	31.02	Gold
Potassium	K 19	39.096	
Silver	Ag 47	107.88	
Sodium	Na 11	22.997	
Sulfur	S 16	32.06	
Tin	Sn 50	118.70	
Tungsten	W 74	184.0	
Zinc	Zn 30	65.38	

FINAL EXAMINATION

Chemistry 144

- I. Blacken the appropriate space on the answer sheet after deciding whether the statement is true or false. Do not guess as your score = number of correct responses - number of incorrect responses.
61. Commercially phosphorus is prepared in an electric furnace with phosphate rock as the source of phosphorus.
 62. The yellow form of phosphorus has a very low kindling temperature and is very toxic. For these reasons yellow phosphorus must be handled with caution.
 63. Yellow phosphorus is used in the manufacture of matches.
 64. Red phosphorus is united directly with calcium in the manufacture of superphosphate.
 65. The acid which is ordinarily called phosphoric acid is H_2PO_4 .
 66. This acid is produced by the action of P_2O_5 upon water.
 67. Na_2HPO_4 is sodium acid phosphate.
 68. An abundance of cheap, pure phosphoric acid has made possible the commercial production of highly concentrated phosphate fertilizers.
 69. Phosphoric acid is an acid because it produces H^+ upon ionization.
 70. Sulfur is found in nature only in the form of its compounds.
 71. Sulfur is not a reactive element.
 72. At room temperature, sulfur may exist in any one of several allotropic forms.
 73. Sulfur burns to produce sulfur dioxide.
 74. Many commercial insecticides and fungicides contain sulfur either as the element or in the form of a compound which releases sulfur slowly.
 75. Hydrogen sulfide is a colorless, odorless gas.
 76. Hydrogen sulfide is non-flammable and non-toxic.
 77. In chemical laboratories hydrogen sulfide is used to precipitate many of the metals.
 78. Hydrogen sulfide dissolves in water to produce a strong acid.
 79. Sulfur dioxide is a colorless, odorless gas.
 80. Sulfur dioxide reacts with water to form sulfuric acid.
 81. Sulfur dioxide is used as a refrigerant and bleaching agent.

82. Paper mills use large quantities of calcium sulfite because solutions of this salt dissolve lignin and leave the desired cellulose behind.
83. Sulfur (or pyrites) is often burned as the first step in the manufacture of sulphuric acid.
84. Large quantities of sulfur are used in the manufacture of vulcanized rubber.
85. 65-75 per cent sulphuric acid is made by the contact process.
86. Fuming sulfuric acid is said to be 120 per cent sulfuric acid.
87. Sulfuric acid is not as strong an acid as is hydrochloric acid.
88. Sulfuric acid is a good oxidizing agent when hot.
89. Sulfuric acid may be used as a dehydrating agent in some cases.
90. Sulphuric acid is a dibasic acid and therefore may form three types of salts.
91. The industrial consumption of sulphuric acid in the U.S. gives an accurate picture of the economic state of the nation.
92. The fertilizer industry is the largest consumer of the less concentrated (65-75 per cent) form of commercial sulphuric acid.
93. The manufacture of explosives requires a pure, concentrated (98-100 per cent) form of sulphuric acid.
94. Organic chemistry is a study of the compounds of carbon.
95. Common materials which consist almost entirely of carbon are soft coal, carbon black, and charcoal.
96. The diamond is composed of carbon.
97. Graphite is an allotropic form of carbon which is often used as a lubricating agent.
98. Most of the carbon black manufactured goes into the production of automobile tires.
99. Carbon can no longer be used for adsorption purposes after it has been activated.
100. One industrial use for carbon is as a reducing agent.
101. Carborundum is calcium carbide.
102. Carbon disulfide is non-flammable and for that reason is very safe for use as a fumigant.
103. Carbon tetrachloride is used in small hand fire extinguishers because it is non-flammable, volatile and its vapors are very dense.
104. Carbon tetrachloride is apt to decompose at high temperatures with the formation of phosgene, a deadly gas.
105. Complete combustion of carbon or any carbon containing compound will give CO_2 .

106. CO_2 is a gas, heavier than air and is formed during the respiration of animals and plants.
107. Great concentrations of CO_2 should be avoided in the laboratory as this gas is a fire hazard and is toxic.
108. Green plants use CO_2 and H_2O for the production of carbohydrate. This process is known as photosynthesis.
109. Respiration in animals and photosynthesis in plants are comparable processes.
110. Dry ice is prepared by allowing liquid carbon dioxide to expand against the atmosphere. Heat is lost during this process and all of the CO_2 is converted into solid CO_2 .
111. Carbon dioxide stimulates the respiration of animals.
112. Carbon monoxide is formed when any compound containing carbon is completely oxidized.
113. Carbon monoxide forms a stable compound with the hemoglobin of the blood and thereby prevents the hemoglobin from carrying oxygen to the tissues.
114. Carbon monoxide is an odorless, colorless gas which is highly toxic.
115. Carbon monoxide is inflammable and is a good source of heat.
116. Carbon monoxide is used industrially as a reducing agent.
117. Na_2CO_3 is sodium bicarbonate.
118. Na_2SO_4 is sodium bisulphate.
119. Gypsum is CaSO_4 .
120. Calcium carbonate is CaH CO_3 .

II. Decide which of the statements (1-15) best describes the word or phrase (nos. 121-135) and blacken the appropriate space on the answer sheet.

- | | |
|----------------------------|-------------------------------|
| 121. Colloids | 129. Peptization |
| 122. Brownian movement | 130. Ultramicroscope |
| 123. Isoelectric condition | 131. Cottrell process |
| 124. Suspensoid | 132. Emulsion |
| 125. Sol | 133. Disperse phase |
| 126. Adsorption | 134. Allotropy |
| 127. Base exchange | 135. Destructive distillation |
| 128. Interface | |
1. Colloidal particles which do not possess a charge.
 2. Displacement of positive ions adsorbed on the surface of a colloid by other positively charged ions.
 3. Concentration at an interface.
 4. A colloidal dispersion of drops in a liquid.
 5. The heating of any material in the absence of air with the continuous removal of volatile products.
 6. The portion of a colloidal system which has been dispersed.
 7. Material of colloidal size which has no affinity for the medium in which it has been dispersed.

8. An instrument which allows one to observe the light reflected from the surface of particles in a colloidal suspension.
9. The existence of an element in several different forms.
10. A fluid colloidal suspension of a solid in a liquid.
11. Disintegration into colloid particles through the action of some added chemical.
12. Displacement of a particle in suspension by molecular bombardment.
13. Grains, drops, bubbles, films and filaments in which at least one dimension is intermediate between molecular and microscopic.
14. Precipitation of charged particles suspended in a gas accomplished by the use of a strong electrical field.
15. The junction between two discontinuous phases (such as solid-gas).

SELECTED BIBLIOGRAPHY

References for The Dissertation

- Arnold, Thurman W. The Folklore of Capitalism. New Haven: Yale University Press, 1937. Pp. vii + 400.
- Bell, Howard M. Youth Tell Their Story. Washington: American Council on Education, 1938. Pp. 273.
- Brubacker, John S. Modern Philosophies of Education. New York: McGraw-Hill Book Co., 1939. Pp. xiv + 370.
- Cook, Lloyd A. Community Backgrounds of Education. New York: McGraw-Hill Book Co., 1938. Pp. xi + 397.
- Counts, George S. The Prospects of American Democracy. New York: John Day Co., 1938. Pp. xi + 370.
- Curtis, Francis D. Second Digest of Investigations In The Teaching of Science. Philadelphia: Blakiston Co., 1931. Pp. xi + 424.
- Curtis, Francis D. Third Digest of Investigations In The Teaching of Science. Philadelphia: Blakiston Co., 1939. Pp. 419.
- Edwards, Newton. Equal Educational Opportunity for Youth. Washington: American Council on Education, 1939. Pp. xi + 160.
- Horney, Karen. The Neurotic Personality of Our Time. New York: W. W. Norton and Co., 1937. Pp. xii + 299.
- Learned, William S. and Wood, Bend. The Student and His Knowledge. New York: The Carnegie Foundation for the Advancement of Teaching, 1938. Pp. xx + 406.
- The National Society for The Study of Education. The Thirty-Eighth Yearbook, Part II, "General Education in the American College." Bloomington, Illinois: Public School Publishing Co., 1939. Pp. ix + 382.
- Progressive Education Association, Commission on Secondary School Curriculum. Science in General Education. New York: D. Appleton-Century Co., 1939. Pp. xiii + 591.
- Rainey, Homer P. How Fare American Youth? New York: D. Appleton-Century Co., 1937. Pp. ix + 186.
- Reeves, Floyd W., et al. The Liberal Arts College. Chicago: University of Chicago Press, 1932. Pp. xxxv + 715.
- Rogers, Carl R. Counseling and Psychotherapy. Boston: Houghton Mifflin Co., 1942. Pp. xiv + 445.
- Russell, John Dale, and Judd, C. H. The American Educational System. Cambridge, Massachusetts: The Riverside Press, 1940. Pp. xvi + 554.
- University of Minnesota, Committee On Educational Research. The Effective General College Curriculum As Revealed by Examinations. Minneapolis: University of Minnesota Press, 1937. Pp. xvi + 427.

- Veblen, Thorstein B. The Higher Learning in America. New York: B. W. Huebsch, 1918. Pp. vii + 286.
- Warner, W. Lloyd, and Lunt, P. S. The Status System of A Modern Community. Vol. II. Yankee City Series. New Haven: Yale University Press, 1942. Pp. xii + 246.
- Warner, W. Lloyd, and Lunt, P. S. The Social Life of A Modern Community. Vol. II. Yankee City Series. New Haven: Yale University Press, 1941. Pp. xx + 460.
- Warner, W. Lloyd, Havighurst, Robert, and Loeb, Martin B. Who Shall Be Educated? New York: Harper and Bros., 1944. Pp. xii + 190.

References for Publications Used as Instructional
Materials In The Experimental Course

- Ahrens, M. R., Bush, N. F., and Easley, R. F. Living Chemistry. Boston: Ginn and Co., 1942. Pp. vi + 528.
- Associates of Lore A. Rogers. Fundamentals of Dairy Science. 2d ed. revised. American Chemical Society Monograph Series No. 41. New York: Reinhold Publishing Corp., 1935. Pp. xv + 616.
- Bernal, John D. The Social Function of Science. New York: The Macmillan Co., 1939. Pp. xvi + 482.
- Buswell, Arthur M. Chemistry of Water and Sewage Treatment. American Chemical Society Monograph Series No. 38. New York: Chemical Catalog Co., 1928. Pp. 362.
- Holmes, Harry N. Out Of The Test Tube. 3rd ed. revised. New York: Emerson Books Inc., 1941. Pp. x + 305.
- Martin, Hubert. Scientific Principles of Plant Protection. 3rd ed. revised. New York: Longmans, Green Co., 1940. Pp. x + 385.
- Prentiss, Augustin M. Chemicals in War. New York: McGraw-Hill Book Co., 1937. Pp. xviii + 739.
- Rhodes, H. T. F. Forensic Chemistry. London: Chapman and Hall, Ltd., 1940. Pp. viii + 214.
- Rice, Oscar K. Electronic Structure and Chemical Binding. New York: McGraw-Hill Book Co., 1940. Pp. xiv + 511.
- Riegel, Emil R. Industrial Chemistry. 4th ed. New York: Reinhold Publishing Corp., 1942. Pp. 861.
- U. S. Department of Agriculture. Soils and Men, Yearbook of Agriculture, 1938. Washington: Government Printing Office, 1938. Pp. xv + 1232.

